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The Electro-Platers Hand-Book

By

JAMES H. WESTON

ILLUSTRATED BY
L. ELLIOTT BROOKES

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This book has been written to meet the requirements of platers desiring a practical and yet non-technical work on electro-plating. The subject-matter given herein has been obtained from platers of practical experience, and the construction and operation of the different devices used in the electro-deposition of metals are fully described and illustrated.

It contains useful information for platers and others who wish to become acquainted with the practical art of the electro-deposition of metals and their alloys, including Electro-deposition of Metals, Electro-deposition of Alloys, Electro-plating Dynamos, Electro-plating Solutions and Electro-plating Apparatus.

THE AUTHOR

The Electro-platers Hand-book

ELECTRICAL RULES AND FORMULAS

In order to enable the operator of an electroplating plant to intelligently handle the batteries or dynamo and plating vats and turn out work properly, it is almost absolutely necessary that some knowledge of the fundamental principles of electricity should be had.

Electricity or electrical energy may be generated in several ways—mechanically, chemically and statically. By whatever means it is produced, there are many properties which are common to all. There are also distinctive properties. The current supplied by a battery is of the direct form and will flow continuously until the battery is practically exhausted.

The dynamo current is primarily of an alternating nature or one which reverses its direction of flow rapidly. In use, this alternating current is changed into a direct or continuous current flowing in one direction only, by means of a commutator.

The cause of a manifestation of energy is force, if of electromotive energy, that is to say of electric energy in the current form, it is called electromotive force. What this condition of excitation may be is a profound mystery, like gravitation and much else in the physical world. The practical unit of electromotive force is the volt.

When electromotive force does work a current is produced. The practical unit of current is the ampere.

A current of electricity passes through some substances more easily than through others. A current of one ampere is maintained by one volt through a resistance of one practical unit. This unit is called the ohm.

The volt, the unit of electromotive force, will generate a current of one ampere in a circuit having a resistance of one ohm. There are several specified equivalents for estimating the exact value of one volt, but these usually refer to the determined capacity of some given type of dry cell.

The ampere, the unit of current strength, has been fixed as the equivalent of a current strength which can deposit .00033 grams of metallic copper, by the electro-plating process, in each second of time. In this respect it measures not only the current intensity, or available working energy, but also the rapidity of its work. The work above stated might readily be accomplished by a given current in ten seconds, instead of in one, but such a current would not have the value of one ampere, only of 1-10 ampere—since it would require ten times as long to accomplish the same result.

An analogy for the ampere is the miner's inch, which represents the product of an orifice one inch square, through which water is allowed to escape from a tank, by the height of the column of water in the tank, in inches. The miner's inch is, therefore, in the first place, a measure of rate or velocity, giving inch-seconds, or the number of cubic inches of water passed in each second of time. Thus, while water flows at the rate of so many miner's inches, the electrical current flows at the rate of so many amperes, the rate per second, in both cases, being directly relative to the original pressure at the source. It is inaccurate to speak of an ampere per second, since such an expression means simply a current of one ampere. In speaking of a current of ten amperes, it does not refer to the amount of current passed in ten seconds, but to that passing in one second.

The ohm, the unit of resistance, measures not only the relative resistance of a circuit composed of a conducting wire of a given length and diameter, as compared with wires of different length and diameter, composed of the same material, but also the specific resistance, which refers to the variations in resistance found between wires of the same length and cross-section, but of different materials. The different resistance of different metals, as found in circuits, precisely similar in all other dimensions, is demonstrated in the fact that, while a silver wire shows a conductivity of 100, and one of copper, 99, a wire of iron gives only 16.80.

Ohm's Law. This law expresses the relation in an active electric circuit of current, electromotive force or voltage and resistance. These three factors are always present in such a circuit. Its general statement is as follows:

In an active electric circuit the current is equal to the electromotive force divided by the resistance.

This law can be expressed in various ways as it is transposed. It may be given as a group of rules, to be referred to under the general title given above.

1. The current is equal to the electromotive force divided by the resistance.

$$C = \frac{E}{R}$$

2. The electromotive force is equal to the current multiplied by the resistance.

$$E = C \times R$$

3. The resistance is equal to the electromotive force divided by the current.

$$R = \frac{E}{C}$$

4. The current varies directly with the electromotive force and inversely with the resistance.

5. The resistance varies directly with the electromotive force and inversely with the current.

6. The electromotive force varies directly with the current and with the resistance.

This law is the fundamental principle in most electric calculations. If thoroughly understood it will apply in some shape to almost all engineering problems. The law will be illustrated by examples.

Single Conductor Closed Circuits. These are circuits embracing a continuous conducting path with a source of electromotive force included in it and hence with a current continually circulating through them.

Example: A battery of resistance 3 ohms and electromotive force 1.07 volts sends a current through a line of wire of 55 ohms resistance. What is the current?

Answer: The resistance is $3 + 55 = 58$ ohms. By rule 1 the current is $1.07 \div 58$, which gives .01845 of an ampere.

A point to be noticed here is that whatever is included in a circuit forms a portion of it and its resistance must be included therein. Hence the resistance of the battery has to be taken into account. The resistance of a battery or generator is sometimes called internal resistance to distinguish it from the resistance of the outer circuit, called external resistance. Resistance in general is denoted by R, electromotive force or voltage by E, and current by C.

BATTERIES

A battery is rated by the resistance and electromotive force of a single cell. In the case of storage batteries, whose susceptibility to polarization is very slight, the resistance is often assumed to be negligible.

There are two resistances ordinarily to be considered, the resistance of the battery which is designated by R or by *n* times R if the number of cells is to be implied and the resistance of the external circuit which is designated by *r*.

The current given by a battery is equal to its electromotive force divided by the sum of the external and internal resistance, that is

$$C = \frac{E}{R + r}$$

Example: A battery of 5 cells arranged to give 7.5 volts, with an internal resistance of 10 ohms, sends a current through a conductor of 12 ohms resistance. What is the strength of the current?

Answer: Current = $7.5 \div (10 + 12) = .34$ of an ampere.

Arrangement of Battery Cells. In practice the cells of a battery are arranged in one of three ways. All may be in series, all may be in parallel, some may be in series and some in parallel, so as to represent a rectangle.

Other arrangements are possible. Thus the cells may represent a triangle, beginning with one cell, followed by two in parallel and these by three in parallel and so on. This and similar types of arrangement are very unusual and little or nothing is to be gained by them.

The electromotive force of a battery is equal to the voltage of a single cell, multiplied by the number of cells in series.

The resistance of a battery is equal to the number of its cells in series, multiplied by the resistance of a single cell and divided by the number of its cells in parallel.

Example: A battery of 50 gravity cells 1 volt, 3 ohms each is arranged 10 in parallel and 5 in series. What is its resistance and electromotive force?

Answer: Resistance $= 5 \times 3 \div 10 = 1.5$ ohms.

Voltage $= 5 \times 1 = 5$ volts.

The same battery is arranged all in parallel, what is its resistance and voltage?

Answer: This gives one cell in series.

Resistance $= 1 \times 3 \div 50 = .06$ ohm.

Voltage $= 1 \times 1 = 1$ volt.

The same battery is arranged all in series, what is its resistance and voltage?

Answer: This gives one cell in parallel.

$$\text{Resistance} = \frac{50 \times 3}{1} = 150 \text{ ohms.}$$

$$\text{Voltage} = 50 \times 1 = 50 \text{ volts.}$$

The current given by a battery is obtained from these rules and from Ohm's law.

As the difference between these arrangements can be more clearly shown by illustrations than by a voluminous description, diagrams are here given to illustrate the different arrangements. At A in Figure 1 the cells are shown arranged in series, the zinc in one cell being connected to the carbon of the next, and so on through the whole line of cells. By this arrangement the electromotive force or power of each cell is added to that of its neighbor, and the internal resistance of each cell is added in a similar manner. But only the volume of current generated in one cell is had. This is shown by the following figures, calculated according to Ohm's law. Supposing the electromotive force of each cell to be 1.80 volts, and the interal resistance of each cell 0.06 ohms, then, taking three cells in series, the figures will be:

$$\frac{1.80 + 1.80 + 1.80 = 5.40 \text{ volts}}{0.06 + 0.06 + 0.06 = 0.18 \text{ ohms}} = 30 \text{ amperes.}$$

But, if only one cell is taken, the figures will be;

$$\frac{1.80 \text{ volts}}{0.06 \text{ ohms}} = 30 \text{ amperes.}$$

The difference being, in the first case a current of 30 amperes at a pressure of 5.40 volts, while in the second case the same current of 30 amperes, but at a pressure of only 1.80 volts. At B in Figure 1 the cells are shown arranged in parallel, the zincs being all coupled to one conductor, and the carbons to the other conductor of the circuit. By this arrangement the three cells are in a combination equal to one large cell, and get the electromotive force voltage of one cell divided by one-third of its resistance, since there are now

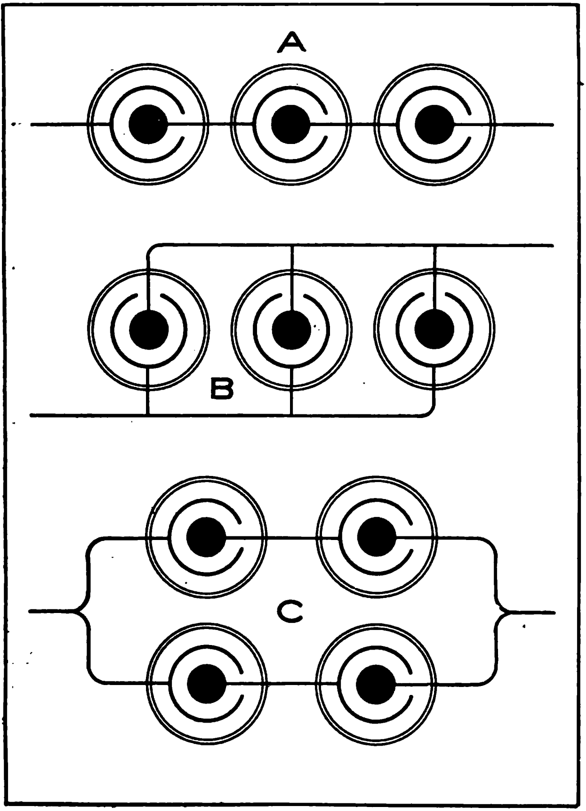

Fig. 1. Arrangement of Battery Cells.

three paths of equal resistance open to the passage of the current. The figures therefore are:

$$\frac{1.80}{0.06 \div 3 = 0.02} = 90 \text{ amperes,}$$

with a voltage of only 1.80 volts. When the external resistance of the circuit is added to the internal resistance of the battery, far different results of a more practical value are given. Supposing, for instance, that the resistance of solution, slinging wires, and leading wires amount to the total of 1 ohm, then the figures will be, in the first arrangement:

$$\frac{1.80 \times 3 = 5.40}{0.06 \times 3 + 1.00 = 1.18} = 4.57 \text{ amperes.}$$

While in the second arrangement the following result would be given:

$$\frac{1.80}{0.02 + 1.00} = 1.76 \text{ amperes.}$$

This shows how useless it is to couple up cells in parallel to a high resistance in the outer circuit, such as would be met with in actual plating practice. But, if four cells are coupled, as shown at C in Figure 1, which may be described as coupling in parallel series, the following results are given:

$$\frac{1.80 \times 2 = 3.60}{0.03 \times 2 + 1.00 = 1.06} = 3.39 \text{ amperes.}$$

Thus, by arranging the cells in groups, in either series, parallel, or parallel series, the required volume of current through the work is obtained at the voltage suitable to the deposition of the metal in a proper condition. It is preferable to so arrange the cells, as shown, instead of dividing the circuit, or adding resistances to keep back the current.

ELECTRO-PLATING WITH BATTERIES

The first experiments in electro-plating were carried out with current derived from galvanic batteries. Its application to commercial uses was also made by the same means. Some good work on a large scale has been done with current from batteries. Although, in large workshops, the battery as a generator has been quite superseded by the dynamo, it still retains its place in small shops and in the home of the amateur electro-plater. When operations in a small way have to be conducted at intervals in small shops where power cannot be readily obtained to drive a dynamo, the use of a battery becomes a necessity, and is a less costly generator than a plating dynamo with its accessories.

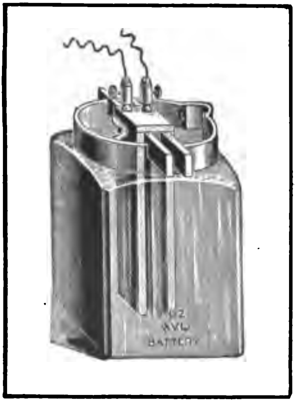

Fig. 2. Single Liquid Type of Plating Battery.

Batteries used for electro-plating are of two forms, single and double liquid types. In the first-mentioned form the elements, which usually consist of carbon and zinc plates or cylinders, are immersed in the same solution, while in the double liquid form the carbon element is in one solution in a porous cup in the center of the containing vessel or jar and the zinc element surrounds the porous cup in another solution.

A battery of the single liquid type is shown in Figure 2, in which the carbon and zinc elements are attached on either side of a wooden support. To charge this form of battery, add 1 part (by volume) of sulphuric acid to 8 parts of water, when cool add 2 parts (by weight) of nitrate of soda. Chromic acid or bichromate of soda may be used instead of the nitrate of soda as a depolarizer, but are much more expensive.

Fig. 3. Double Liquid Type of Plating Battery.

A double liquid type of battery is shown in Figure 3. To properly charge such a battery, add 1 part of sulphuric acid to 10 parts of water, when cool put in the containing vessel or jar in which the zinc element goes. If chromic acid is used as the depolarizing agent in the porous cup, use 2 parts (by weight) of chromic acid to 10 parts (by volume) of water. When either bichromate or nitrate of soda are used, the propo tions should be as follows: Water 8 parts, sulphuric acid 8 parts (by volume), bichromate or nitrate of soda (by weight) 2 parts. The zinc elements should be kept well amalgamated and always removed from the cell when the battery is not in use.

The single liquid type of battery has a voltage of from 1.63 to 1.75 volts per cell, while the double liquid battery has a voltage of about 2 volts per cell.

The positive pole or carbon of the battery should always be connected to the anodes in the plating solution and the zinc or negative to the cathodes or work being plated.

Construction of Batteries. The construction of batteries for electro-plating must be governed by the requirements of the work. These usually demand a full, constant current at a low voltage. To insure the first condition, large cells must be used and have electrodes with a large surface. The cells should be not less than one-half gallon in size, and may be of ten-gallon size with advantage. The electrodes must be large, to correspond with the cells, but there should be at least one inch free space below the plates when they are fully immersed. This space being necessary to prevent short circuiting and local action caused by particles of metal falling from the electrodes to the bottom of the cell. It is a well-known rule, that the surface of the plates in a battery should exceed that of the anodes in the depositing solution, and these should present a surface slightly in excess of the surface to be plated. When the cells are arranged in series, only the surface of the electrodes in one cell can be taken into account, all the others being employed in forcing the current through the resistance in the circuit. Large cells and large electrodes insure a low internal resistance of the battery, and consequently more force for use in the outer circuit, since the strength of the current will be equal to the voltage of the battery divided by all the resistances in the circuit. To insure constancy, both the exciting and the depolarizing liquids must be in a condition to work through the required time.

Amalgamation of Zinc. The zinc plates used in batteries are rarely made of pure metal. Even the best rolled zinc contains impurities. The effect of these impurities is seen in local action, in which the impure zinc forms with the purer particles a number of galvanic pairs. By coating the zinc with mercury, this tendency to local action is reduced to a minimum. As the zincs come from the maker, they are coated with a greasy film, unless sent out amalgamated. To remove this film, dip the zincs in hot water in which some washing soda has been dissolved, and rinse them in clean water. Pour some mercury in a shallow dish, such as a baking dish or a porcelain tray, and cover the mercury with a mixture of sulphuric acid and water, made by adding 1 part by measure of sulphuric acid to 3 or 4 parts by measure of water. Some caution is always required when adding this acid to water, as the acid combines with the water in such a violent manner as to cause great heat and spurting of the mixture. The consequences might be serious damage to skin and to clothing, as the acid is very corrosive and will quickly destroy clothing. Therefore, always add acid to the water slowly, but never add water to the acid.

Place the zincs in the dilute acid and brush the mercury all over their surface with a brush made of fine steel wires, until all the surface has been made bright with the mercury. Then set the zincs aside in an empty dish to drain off the surplus mercury. Zincs must be reamalgamated in a similar manner when any part of them have lost their coat of mercury, and bare gray patches appear on them whilst being cleaned. A wide bristle brush will be found a very useful article for brushing zincs after use in the battery. When zinc cylinders are used, the insides must receive the most attention, as these are the parts subject to the action of the acid. Set the zincs in empty jars when not in use, to catch the mercury draining from them.

ELECTRO-PLATING DYNAMOS

The evolution of the dynamo may be said to date from the time when it was discovered that an electric current passing through a coil of wire produced an inductive effect on a magnetic needle placed beneath it, or, in other words, an electric current passing through a wire exerted magnetic effects on iron and steel placed near the wire. This discovery led Michael Faraday, in 1831, to infer that, since a magnetic effect could be produced in iron by a current of electricity, a magnetized piece of steel in motion should produce an electric current. A long spiral or helix of copper wire was therefore procured and its ends connected with a galvanometer. A powerful bar magnet was then introduced into the spiral of wire. This being done, a deflection of the galvanometer needle took place instantly when the bar magnet was placed in the coil, and an opposite deflection was caused when the magnet was withdrawn. This discovery led to the construction of a machine in which a disc of copper connected by wires to a galvanometer was caused to revolve between the poles of a powerful horse-shoe magnet, and thus set up a current of electricity in the wire. Other experimenters followed on the same lines, and in the course of a few years the magneto-electric machine was so far developed as to produce brilliant sparks, give powerful shocks, and also effect chemical decomposition.

Principle of a Dynamo. A dynamo-electric machine is a machine constructed to convert dynamic or mechanical force into electric energy. It has been already shown that a moving bar magnet will induce a current of electricity in a helix of copper wire surrounding the magnet. The influence of a magnet is not only felt in a wire wrapped around its polès, but extends to a considerable distance beyond them. In the case of a horse-shoe magnet the magnetic influence fills the space between the poles, and extends beyond them. This space, thus filled with magnetic lines of force, is called the magnetic field. If some turns of insulated copper wire are wrapped around a bar of iron, and it is caused to move in this magnetic field so as to cut the lines of force, a current of electricity will be induced in the turns of wire wound on the iron bar, by the cutting of the lines of magnetic force through which it moves. If some insulated copper wire be wound around the legs of the magnet, a current of electricity will be set up in the magnet coils as well as in the coils of wire surrounding the iron bar. It may be mentioned that in the field of a horseshoe magnet there is a neutral zone in which there are few lines of magnetic force to be cut by the moving bar. It follows, therefore, that the electric inductive influence of the magnet on the armature coils will be greatest where the lines of force cut are the most dense. As the armature is made to move in the magnetic field, there will be two strong magnetic impulses and two reversals. If the ends of the armature coil are connected with the ends of the magnet coil so as to send the strong impulses through this coil in one continuous direction, the effect of this current of electricity flowing through the magnet coils will be an increase of magnetic strength in the magnet. This is done in a dynamo by means of a device known as a commutator. A commutator is made in the form of a split ring of brass mounted on an insulated hub, and fixed on the shaft of the armature. The two ends of the armature coils are connected with the two sections of the commutator, and the current is collected from these by two strips of metal called brushes. In some armatures there are several coils. When this is the case, the commutator has as many segments as there are coil ends, but the action is the same. As the coil of wire passes out from the most intense part of the magnetic field into the comparatively neutral zone, the impulse given to it is interrupted by a division in the commutator, and diverted by way of the brush to the magnet coil or to the outer field. In this way a current of electricity is generated by the rotation of the armature in the coils of wire wound on it and also on the field magnets, and the machine thus becomes a generator of electricity.

Selecting a Plating Dynamo. The resistance of the plating solution, the slinging wires, and the wires conducting the current from the dynamo to the vat being known, the armature of the dynamo should be wound with wire offering a resistance of one-twentieth the working resistance of the outer circuit. The field magnets should be wound with wire having a total resistance of 400 times that of the armature, or 20 times the total resistance of the outer circuit. The armature coils should be connected in shunt with the coils of the field magnets, to insure uniformity of the current under varying loads, and to prevent reversal of the magnetism in the dynamo by the current being sent through the field magnet coils in the wrong direction. It should be understood that all solutions, through which a current has been passing, form in themselves a galvanic battery, with the articles being plated and the anodes as elements. The plated articles being the positive elements, and the anodes the negative elements, in this galvanic battery, the current generated is therefore opposite to that employed in the work of electro-plating. If the coils of the field magnets of a dynamo are connected in series with those of the armature and the outer circuit, the back current from the solution will rush around the coils immediately after stopping the dynamo, or on slowing down its speed, and will reverse the poles of the field magnets by inducing in them an opposite condition of magnetism to that existing while the dynamo is in proper working order. This is prevented by connecting the field magnet coils in shunt with the armature, and should the back current from the solution become sufficiently powerful to pass round the field magnet coils, it passes through them in the same direction as it is sent by the dynamo itself, and does not reverse the permanent magnetism of the field magnets.

In a dynamo wound for electro-plating, with the coils connected in shunt, the magnetism of the field magnet cores will be proportionate to the resistance in the outer circuit. If there are several articles suspended in the solution, and a proportionate surface of anode, the resistance of the outer circuit will be low, and the greater volume of current will flow by the path offering least resistance, which will be, in this case, through the solution. As a consequence, only a small portion of the current will pass around the field magnet coils, and thus the magnetic intensity of the fields will be low. If, on the contrary, the resistance in the plating vat is high, when only a few articles are immersed in the solution, the path of least resistance will be by way of the field magnet coils, the armature current will flow by this path, increase the intensity of the magnetic field, and raise the tension of the current, thus enabling it to overcome the increased resistance in the plating vat.

Choice of a Dynamo. In the early days of plating dynamos for electro-deposition, the makers were few and far between. At the present time almost any maker of dynamos can make a machine for electro-deposition. In choosing a new dynamo, see that it is shunt wound, that is, that the wires from the field magnet coils are connected one to each brush, and that the terminals which lead to the outer circuit are also connected one to each brush. Although the series machine is cheaper to operate for a given output, yet it is sure to be subject to reversal sooner or later. Mechanical devices are in use to prevent the injurious back flow of the current from the vat, but these are not always reliable. Compound wound machines, which possess both shunt and series coils, are equally liable to reversal, but these machines are very suitable for special work requiring a constant low voltage through varying resistances in vats connected in parallel with the dynamo. The output of the dynamo should be expressed in amperes, but some makers express the output by so many square feet of exposed cathode surface, thus giving the plater some idea of the surface of goods he can cover at the same time. The dynamo chosen should have a broad, firm base, so as to stand steady while running. Its bearings should be long, and provided with means to keep them well lubricated, to prevent heating while at work. It must be well ventilated by air spaces between the coils, to keep them cool while the machine is working. Heating of the coils and bearings means a loss of power in the outer circuit, and a loss of driving power, since heat absorbs the force which should be converted into electricity. The driving pulleys should have broad, smooth surfaces, to prevent loss of power by slipping belts, and the machine should be driven from a countershaft. All wearing parts should be so arranged as to be easily got at and removed for repair. This applies specially to the brushes, brush-holders, and commutator. The brush-holders should not be fixed to any part of the machine, but should be attached to a rocker arm, pivoted in such a manner as to allow of free movement through an arc of a circle, for the easy adjustment of the brushes to any angle. The commutator segments should be of hard copper. The brushes may be of carbon or fine copper gauze. The brush-holders should be pivoted on the rocker arm and furnished with springs to exert an equal pressure on the brushes.

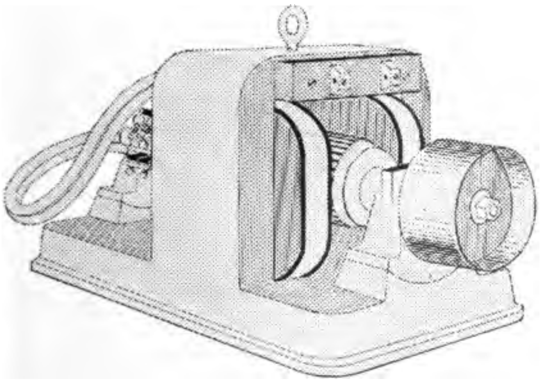

Fig. 4. Plating Dynamo of the Weston Type.

Plating Dynamo. A plating dynamo of the **Weston** type is illustrated in Figure 4. These dynamos may be either shunt or compound wound. The frame and pole pieces are of cast steel. For the frame a special soft grade is used, having a high magnetic permeability. The field coils are made of insulated copper wire wound compactly by machinery, insuring the maximum ampere turns without great bulk. The whole coil is properly insulated and protected from mechanical injury. The armature is of the toothed type and is most carefully constructed. The core is built up of thin soft steel discs. Each disc is insulated on both sides and assembled on a spider constructed to insure the greatest amount of ventilation.

The armature coils are made in a form and perfectly insulated. The slots in which the coils rest are also insulated, so there is no chance for a ground.

The segments of the commutator are forged from pure copper carefully insulated with the best mica. The radials from the bars are so arranged that a steady current of air is thrown on the commutator and brushes.

The bearings are self-aligning, and the boxes made of special bronze, and provided with large oil wells and automatic oiling rings.

These machines are said to run continuously under full load with a rise of temperature above the surrounding atmosphere not exceeding 8 degrees Centigrade (46 degrees Fahrenheit) in windings, and somewhat less in the commutator. The commercial efficiency is said to be

85 per cent, and the electrical efficiency 93 per cent.

Compound versus Shunt Wound Plating Dynamos. A little information as to the merits of compound as opposed to shunt winding may not be out of place. The shunt wound dynamo has only one winding on its field magnets, in which only a portion of the current generated passes through the field winding and in operation will lower its voltage as the tanks are filled with work, while the brushes have a tendency to spark on the commutator, which necessitates their regulation from time to time as the load increases or decreases.

These particularly undesirable features are due to the method of winding of a shunt wound dynamo, which permits only a small portion of the current generated by the armature to pass through the field coils, while at the same time the armature reaction is constantly tending to reduce the field magnetism, which in many types of shunt wound machines makes necessary an exciter in the shape of a small dynamo, in order that the fields may be properly charged. This current from the exciter must be regulated as the load on the dynamo is increased or diminished.

Under these conditions more time must be consumed in plating a given batch of work than would be necessary if the dynamo was of compound type, while the sparking of the brushes on the commutator as load is increased or decreased requires frequent renewal of the latter.

In the plating room where there are a number of tanks containing different solutions of varying densities, or of solutions requiring a difference in voltage for the successful production of work, the disadvantage of a shunt machine is apparent for the reason that when a tank is emptied and so much load is taken from the machine, the voltage will increase in all the other tanks, thus making necessary a constant watchfulness on the part of each man in charge of a tank, or work may be burned. There are other disadvantages which always apply to the shunt wound type of dynamo.

Compound Wound Plating Dynamo. A compound wound dynamo has two distinct windings on its field magnets, one of very many turns of fine wire, called the shunt winding, and another known as the series winding, which latter consists of a number of turns of heavier gauge wire. The series winding is in series with the vats or external circuit. The current that is used in the vats, passing through this winding, increases the magnetism of the field as the load increases, and thus the drop in voltage, which would otherwise occur by reason of the increased drop in the armature winding and increased magnetic reaction caused by the armature current, is provided for.

Speed of Plating Dynamos. Plating dynamos are built to run at lower speeds than electric lighting dynamos, because the voltage of a plating current is lower than that employed for electric lighting. The voltage of the current from a dynamo largely depends upon the speed of its armature. As each yard of active wire on an armature coil is capable of developing one volt when driven at a circumferential velocity of 1,250 feet per minute, the voltage of the current from a dynamo may be readily calculated if the length of the active wire on one of its armature coils and the speed at which the armature is driven be known. The circumferential velocity of the armature may be ascertained by measuring its diameter, multiplying this by 3.14 to find the circumference, and then by the speed of the armature. To increase the voltage of the current from a machine its speed must be increased, and to lower the voltage the speed must be decreased. Plating dynamos are usually driven at speeds varying from 700 to 1,500 revolutions per minute. The speed can be ascertained by counting the revolutions of the driving pulley and calculating the speed of the pulley driven by it, or the speed of the armature shaft may be taken direct by means of a speed indicator.

Dynamos, Efficiency of. The limit of efficiency of a dynamo is at the point where the voltage or pressure ceases to be strong enough to deposit metal to the best advantage. In shunt wound machines the voltage usually drops below the desired pressure when from one-half to two-thirds of the ampere capacity is being taken out. Compound wound dynamos will maintain the same pressure up to the full rated capacity of their amperage, and it is for this reason that from compound wound dynamos an efficiency of from one-third to one-half more can be obtained over shunt wound machines of the same rated capacity.

ELECTRO-PLATERS MATERIALS

In a well organized electro-plater's shop there are many appliances necessary besides plating batteries and dynamos for properly performing the work. Some of these are necessaries, without which not even the most simple operation may be done, while others may be termed conveniences for facilitating larger operations or work of a more intricate nature. Platers working even in the smallest way with a plating battery must have suitable vessels for holding the plating solutions and the various pickles used in preparing the work. Slinging wires are necessary for holding the articles in the solutions, and suitable brushes for cleaning the work before being plated and finishing its surface afterwards. Among conveniences may be mentioned a selection of revolving scratch brushes, and a lathe for revolving them, a similar selection of small polishing wheels, made of different materials, and denominated dollies, mops, bobs, etc.. together with a suitable machine for working them, a set of hand brushes for cleaning and polishing, and a set of burnishers if silver and gold plating is to be done.

Plating Vats. Although the outer containing box is made of strong wood with well-fitting joints, this material alone is not suitable for plating solutions, since the wood absorbs a large quantity of the solution, and the salts creep over the sides. The frame must therefore be lined with a material impervious to the speedy action of the cyanide, such as a coating of asphaltum, but better yet is sheet lead, this will resist the action of the cyanide for many years, but all joints must be made by burning instead of soldering, as solder will form with lead a galvanic pair, and a galvanic action will soon corrode the joints. The lead-lined tank must then be lined with match-board, to prevent the accidental contact of the articles with the lead lining, and the upper rim of the vat should be framed with strips of wood boiled in paraffine, to prevent the internal absorption and creeping of the salts.

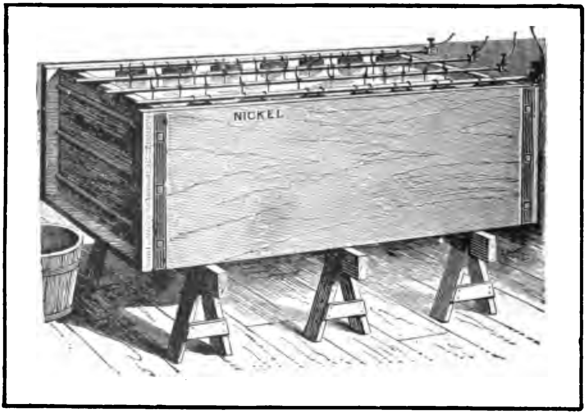

Fig. 5. Nickel-plating Tank.

Plating vats should be selected with a view to the magnitude of the operations to be performed in them. If the operator desires to plate a few rings, scarfpins, brooches, studs, sleeve-links, solitaires, and similar small articles, a suitable vat is an enameled iron saucepan holding from one to two pints of liquid, or a stoneware salt-jar immersed in hot water in a saucepan, but if watch-chains, watch-cases, and similar longer or more bulky goods are to be plated, a larger pan or vat must be obtained. If the operations are to be extended to a larger trade, a larger enameled iron vat, capable of holding from five to ten gallons, will be required, and this must be heated over a suitable furnace, or over an atmospheric gas-burner, or by means of a steam-jacket. The two last means are preferable, as being more

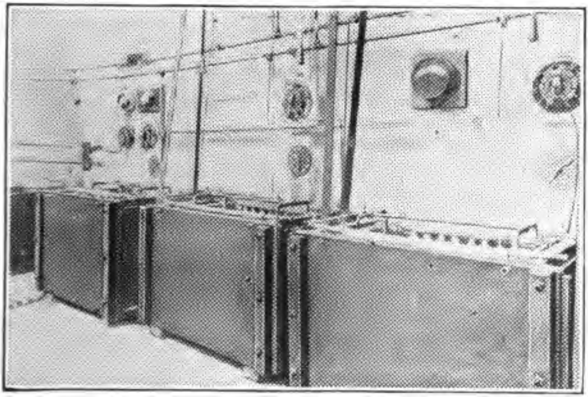

Fig. 6. Group of Plating Tanks.

under control than the first. It must be understood at first, that the vat for gold-plating solutions must be impervious to the attacks of potassium cyanide when heated to a temperature of from 150 to 180 degrees Fahrenheit. All metals except platinum are soluble in hot cyanide solutions, and nearly all other substances, except glass, vitrified stoneware and enameled iron.

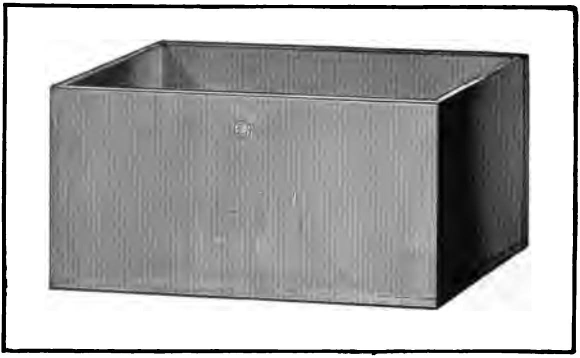

Fig. 7. Glazed Stoneware Tank.

Figures 5 and 6 show different styles of plating vats.

Plating tanks for very large work are usually made of wood and lined with a thick coating of asphaltum.

Tanks. Tanks for use with acid should be of glass or glazed stoneware, enameled wrought iron tanks are more suitable for potash and alkaline solutions. A heavy glazed stoneware tank is shown in Figure 7. For small work a good quality of white enameled iron cooking utensil may be used for the potash solution.

Heating Tanks. Large tanks for heavy work are usually made of cast iron and heated by a steam coil in the bottom of the tank. Such tanks are used for solutions that must be kept hot, such as lye, rinsing water, cleaning compound and cyanide solutions. These tanks, along with the steam chamber, are cast in one piece. A pair of the tanks are illustrated in Figure 8 in position and ready for use.

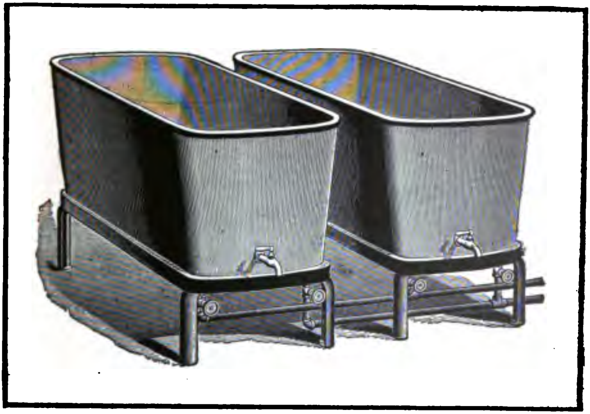

Fig. 8. Steam Tanks with Coils in the Bottom of the Tank.

Another form of steam tank or kettle is illustrated in Figure 9. A positive circulation of steam is carried through the channels shown in the drawing in the bottom of the tank. These are extra tanks and adapted for use wherever lye, cleaning compound, water or alkaline solutions are to be kept constantly hot.

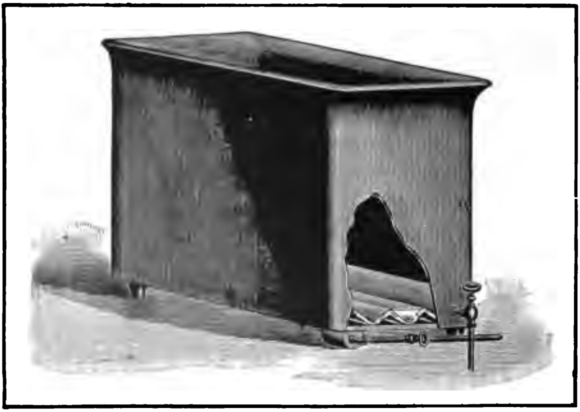

Fig. 9. Steam Kettle with Corrugated Steam Passages.

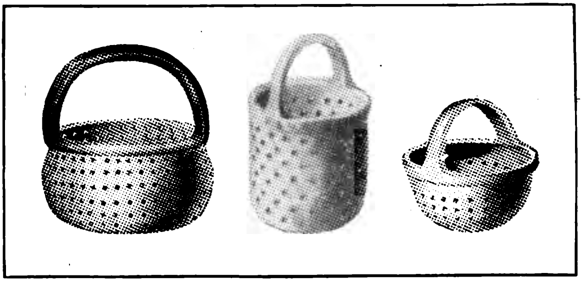

Fig. 10. Glazed Stoneware Dipping Baskets.

Dipping Baskets. Baskets of glazed stoneware are always used when a number of small articles have to be dipped in acid or cyanide solutions.

Fig. 11. Steel or Aluminum Wire Dipping Baskets.

As successful dipping depends more upon quick and careful handling than upon the nature of the dip itself, the holes in these baskets should be as large as possible, to allow of the rapid escape of the acid or cyanide. Three forms of glazed stoneware dipping baskets are illustrated in Figure 10. Woven wire baskets of round or square shape are also used for dipping purposes. They are made of brass, steel or aluminum. Ten different styles of these baskets are shown in Figure 11.

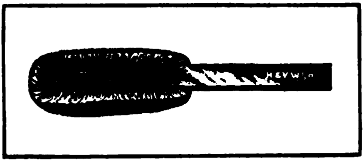

Fig. 12. Potash Hand-brush.

Scouring Brushes. When articles are being cleaned in alkaline solutions to remove grease, brushes made of animal fiber cannot be used, as it would be eaten away by the solution. For this purpose brushes known as potash brushes are used. They are made of hard wood backs fitted

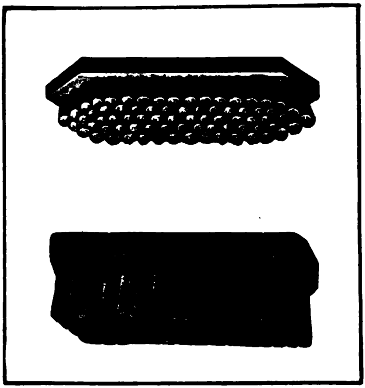

Fig. 13. Potash Brushes.

with knots or tufts of cotton or other vegetable fiber. Some of the many kinds of brushes used for this work are shown in Figures 12 and 13. Brushes used for scouring the work with are illustrated in Figure 14. They are of three forms, as shown, having flat, curved and shoe handles to suit different conditions of work.

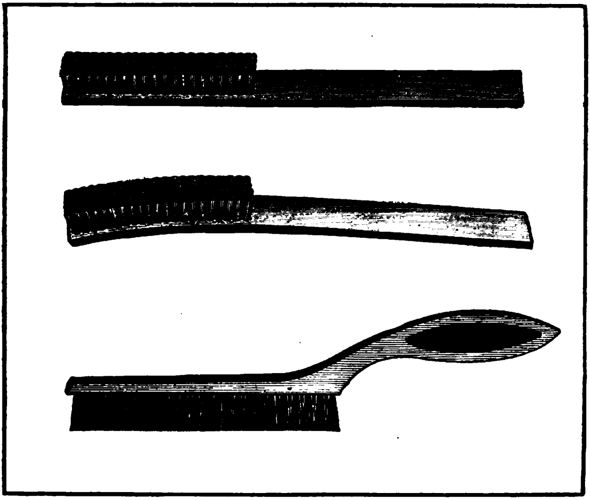

Fig. 14. Scouring Brushes.

They are made with either brass, steel or fiber bristles.

Scratch-Brushes. Brushes intended for the general work of cleaning large surfaces are made of brass or steel wire, and of various degrees of softness according to the gauge of the wire used. These brushes are fitted with wooden hubs, with a hole in the center to fit the spindle of the lathe. Three different forms of scratch-brushes are shown in Figure 15. The one shown in the upper view is for flat work and the two brushes shown in the lower view for cup and goblet work especially. For smaller articles, such as thimbles and rings, the brushes shown in Figure 16 are better adapted, especially for inside work.

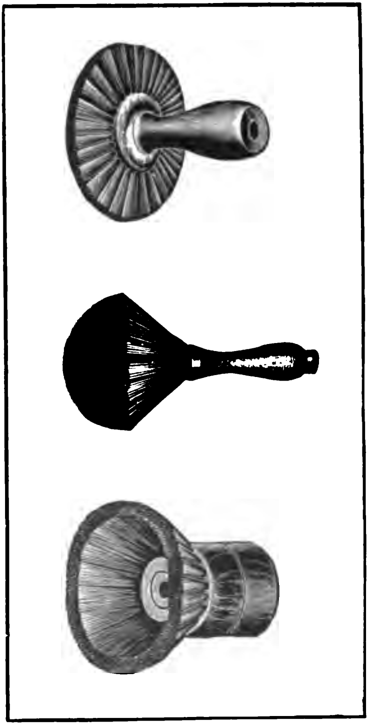

Fig. 15. Scratch-brushes for Flat, Cup and Goblet Work.

Scratch-Brush Lathes. A combination foot-power lathe for use with either small buffing wheels or scratch-brushes is shown in Figure 17. For small jobs these lathes will be found well adapted. A power combination bench lathe is shown in Figure 18.

Dust-Brushes. For removing dust from highly polished gold or silver plated articles, after being dried in hot sawdust, the brushes shown in Figure 19 are well adapted, as they are made of camel's hair.

Polishing Wheels. Wheels or buffs used for polishing articles may be divided into two classes, those for preparing the surfaces to be plated and those for finishing or giving the final polishing during the plating operation. Various forms of polishing wheels and buffs are shown in Figure 20.

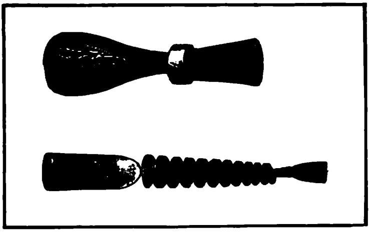

Fig. 16. Scratch-brushes for Thimbles and Rings.

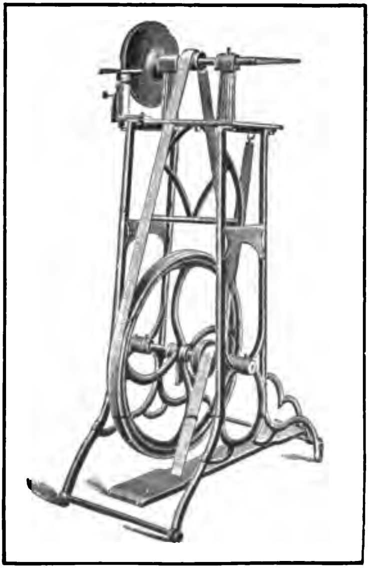

Fig. 17. Foot-power Scratch-brush Lathe.

Polishing Wheels, Directions for Using. Screw on the spindle only tight enough to hold in place. If there is any flutter or side motion, sometimes caused by careless handling or screwing too tight, it can be remedied by side pressure of the hand, or by loosening or tightening the nut on the spindle. Always remember to use care the first time in setting the wheel.

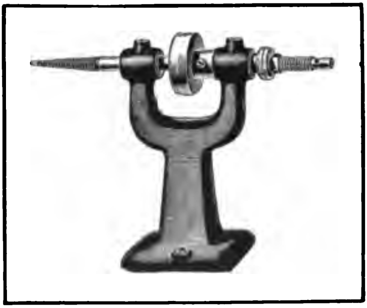

Fig. 18. Power Bench Scratch-brush Lathe.

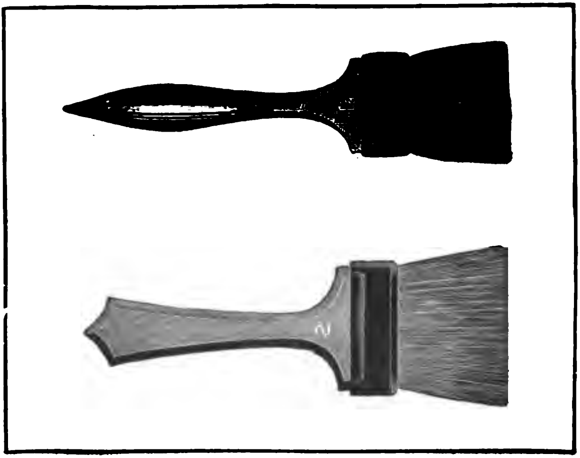

Fig. 19. Camel Hair Dust Brushes.

Run in direction indicated by the arrow on the face.

Soft and medium for silver, nickel work, brass, etc.

Medium for stove, axe, or plow work, and saddlery hardware.

Hard for gold, brass, emery hard grinding, and for grease or oil work.

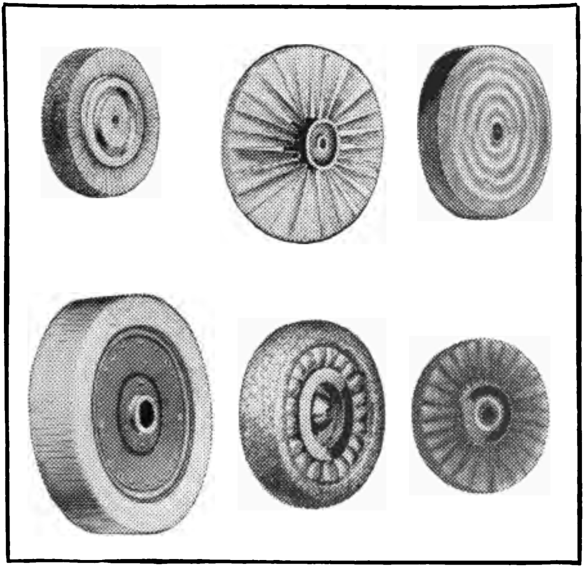

Fig. 20. Polishing Wheels.

Polishing Wheels, Balancing of. All wheels running as fast as they must in polishing. require to be very carefully balanced or they will pound or chatter, making good work impossible. Balancing is accomplished by placing the wheel on an arbor and rolling it on two level, knife-edged strips of metal, one on each side of the wheel. Thus suspended the wheel will stop with its heaviest part downward, and with a little chalk to mark the wheel and some small pieces of sheet lead to fasten on the side of the wheel, balancing is quickly and easily performed. It may also be done by hanging the arbor between cone centers, as pulleys are balanced in a machine shop, but the rolling method of balancing on bars, which is precisely the method the watchmaker employs in poising a watch balance, is the quickest and best.

Leather wheels are used in polishing and fine grinding, where a flexible wheel is necessary. There are many different kinds of wheels which may be classed under this head.

Walrus wheels are made from the tanned hide of the walrus, and are used for work requiring the wheel to be turned up to a thin, moulded edge or curve, as they are thick enough to allow such shapes to be made from a single piece.

Bull neck wheels are made from the thickest and toughest portions of hides, and form a harder wheel than walrus. They are much used in stove, bicycle and other steel and iron work. Other leather wheels are similar in their nature, differing only in the mechanical structure and degree of hardness, the desirable quality being the ability to hold the emery up to the work without allowing any lumps or unevenness in the glued emery to cut into or gouge the work.

Felt wheels are used with emery and glue, or with polishing compositions. They are of varying degrees of hardness and either white or gray. The higher-priced felt wheels are the cheapest in the end, the extra price being more than made up in the increased durability and uniformity of the white wheels, which wear much longer, and give a superior finish, than do the cheaper gray felt wheels.

Cotton buffs are made of discs of muslin and are used with pastes of tripoli, crocus or rouge for finishing or coloring. The hardest buffs are made in sections, from duck, stitched or quilted together, while the soft buffs are muslin stitched only at the center. As many sections as may be necessary to make the desired thickness of wheel are put on the arbor and the flanges set up until the wheel runs properly.

Canvas wheels are made of coarse duck or canvas, cut into discs of the required size and glued or cemented together under pressure, after which they are bored out to receive the arbor, put on the machine and turned up to the required shape.

Emery or corundum wheels are used for grinding off the imperfections on castings caused by breaks in the moulds. These wheels are of varying thicknesses, grades, sizes and shapes and should be run at correspondingly varied speeds in order to get the best results out of them. If run too fast they will glaze and require frequent dressing to keep them sharp. Too much pressure when grinding will also glaze a wheel.

Polishing Lathes. Polishing lathes are, as a rule, made much heavier and stronger than scratch-brush lathes, and have massive cast iron pedestals and extra long bearings so as to stand heavy work at high speeds. The spindles are fitted at their outer ends with screw threads, collars and lock-nuts for clamping the wheels upon them. The work of polishing is best done when the spindle is driven at a high rate of speed, as the greater the surface velocity of the wheel or buff, the better and quicker the finish is imparted to the surface of the work.

Fig. 21. Extra Heavy Polishing Lathe.

An extra heavy polishing lathe is shown in Figure 21, and various forms of spindles for use in the same are illustrated in Figure 22.

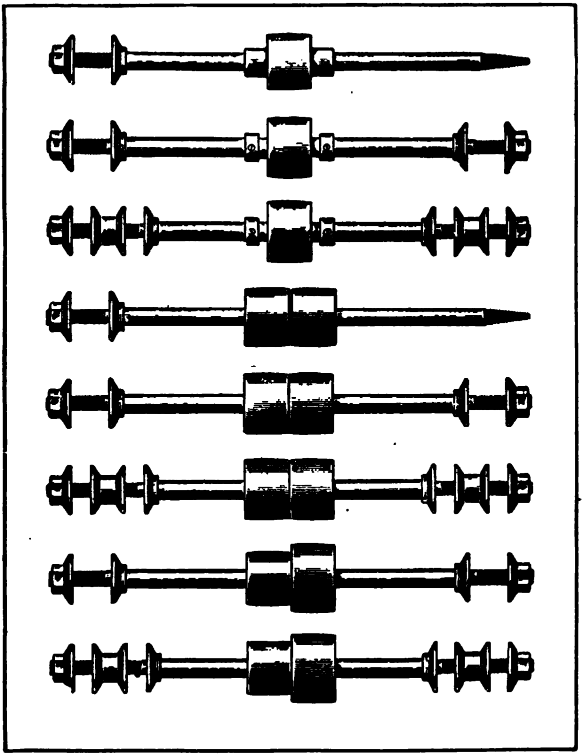

Fig. 22. Spindles for Heavy Polishing Lathe.

Polishing Materials. The materials in use for polishing metals to prepare them for plating are: Finely prepared and sifted sand, lime, rotten stone, pumice stone, and various compositions of emery, crocus, tripoli, and rouge for imparting a high state of finish to the articles. Tripoli, crocus, and rouge, in various grades to suit the work, are made up into cakes or bars. In this form it gives less trouble, and makes less waste than when used in the form of loose powder. The cake of composition is pressed against the wheel or buff whilst it revolves, which then becomes charged with the abrading material and holds it whilst the work of polishing is being done. Tripoli is used in the rough on leather wheels for preparing brass work. The fine tripoli is used on calico buffs for imparting a high finish on brass, copper or steel before it is plated, and in finishing nickel-plated work. Crocus is used for a similar purpose. Rouge composition is used to impart a high state of finish to jewelry, spoons, forks, and electro-plated goods. Pumice stone in fine powder, and rotten stone, are used in scouring goods by hand with brushes in the scouring trough. Pumice stone in lumps, and rotten stone, are both employed as abrading materials to rub down by hand, rough, pitted and corroded surfaces in places difficult to be got at with wheels or buffs.

Tripoli comes in three grades: Coarse, for cutting down rough or hard brass or bronze on hard buffs. Medium, which is used on medium buffs for smoothing and cutting down softer metals. Fine, which is used on soft buffs for coloring on cheap work and for use in place of the harder rouges where the color of the latter is objectionable and is difficult to get out of the work.

Lime. The lime used for polishing is a pure anhydrous lime, obtained from Vienna, and is extensively used where the red color of rouge is objectionable. It must be used while slacking or it is of no value, so it must be kept in the airtight tin or bottle in which it was shipped.

Rouge. This polishing material is used for coloring brass, gold, silver and the softer metals. It is divided into numerous grades, which are distinguished by the names of the metals for which they are used.

Crocus. This substance is an oxide of iron, made by calcining sulphate of iron in great heat and then grading it into polishing powders. The more calcined part is of a bluish purple color, coarser and harder than those portions which have been exposed to a lesser heat, and is called crocus, while the softer and redder portions of the material are called rouge.

Pumice Stone. This material is described as a highly porous, light mineral substance of volcanic origin, resulting from the solidification of foam or scum formed by the escape of steam or gas on the surface of molten lava, and is composed of 72 per cent of silica, 17 per cent of alumina, 2 per cent of iron oxide, and 9 per cent of soda and potash.

Pumice stone is used in powdered form for scouring the work, to remove all traces of oil, grease or lye, just before putting the work in the plating solution, also in lumps, for scouring spots that refuse to take the plating, which is a common fault in replating old goblets, cups and trays that have been badly corroded.

Speed of Wheels. The peripheral speed or circumferential velocity of a polishing wheel or buff should not exceed a maximum velocity of 100 feet per second, or a minimum velocity of less than 70 feet per second, if good work is expected from the wheel or buff. As the wheels or buffs wear down the work proceeds slower and slower, unless cone pulleys are provided on the line shaft and the countershaft of the polishing lathe. The accompanying table gives the maximum and minimum speeds for wheels from 1 to 36 inches in diameter, in revolutions per minute.

SPEED OF WHEELS IN REVOLUTIONS PER MINUTE.

Diameter in Inches.	Revolutions per Minute.		Diameter in Inches.	Revolutions per Minute.	
	Minimum.	Maximum.		Minimum.	Maximum.
1	13,000	18,000	9	1,760	2,460
1½	10,000	14,000	10	1,580	2,210
2	7,900	11,000	12	1,320	1,850
2½	6,330	8,800	14	1,130	1,580
3	5,275	7,400	16	990	1,380
3½	4,500	6,300	18	880	1,230
4	3,950	5,500	20	790	1,100
4½	3,500	4,900	22	720	1,000
5	3,160	4,400	24	660	920
6	2,640	3,700	26	600	850
7	2,260	3,160	30	500	735
8	1,980	2,770	36	400	585

Wheel Truing Device. A wheel truing device for balancing polishing wheels of all kinds, iron pulleys or emery wheels, is shown in the upper view in Figure 23. The cones will take four sizes of arbors, and are usually furnished with the machine.

Wheel Cleaning Machine. A wheel cleaning machine is illustrated in the lower view in Figure 23. By placing the worn wheel in this machine, and letting it run a few minutes with the water just touching the rollers, all of the glue and emery will be removed without damaging or loosening the leather covering.

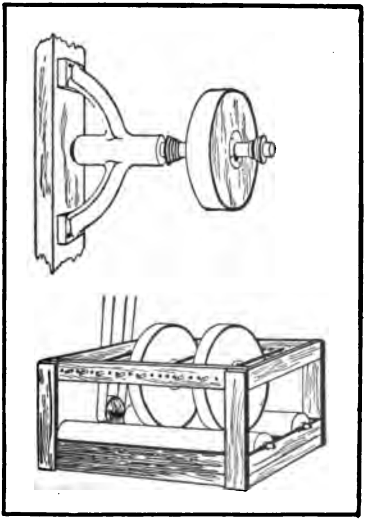

Fig. 23. Wheel Truing Device and Wheel Cleaning Machine.

This machine has two rows of movable rods to keep the wheels from falling over. The idle roller also has two positions for different diameters of wheels. The speed of the machine should be about 20 revolutions per minute.

Belt Straps are made of canvas or duck, from one to two inches wide, glued and set up with emery as previously described, and used in polishing flat surfaces, such as cutlery, flat springs, large tubes for bicycle frames, etc. They are run on flanged pulleys, one of which is supported on a standard and the other, which is the driver, is sometimes mounted in place of a wheel on one of the polishing heads.

Belt Strapping Machine. This belt strapping device shown in Figure 24 is simple in construction and easily operated. It is designed with a view of meeting the requirements of the large variety of work which experience has shown can be economically and rapidly polished or roughed off by this method. The facility with which this machine can be operated makes it applicable for many small articles heretofore polished on regular wheels.

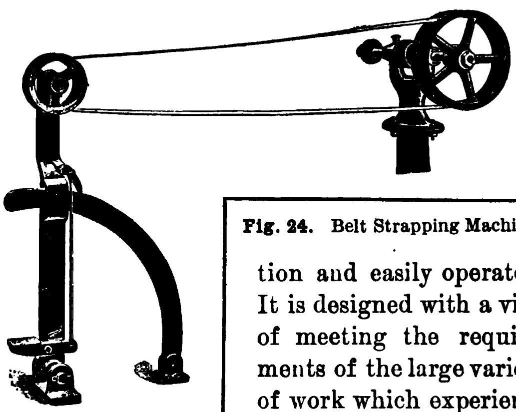

Fig. 24. Belt Strapping Machine.

This attachment can be used to great advantage by manufacturers of bicycles and bicycle parts, brass cocks, and other plumbers' fittings, gas fixtures, grate and fender work, while for cutlery it seems to be indispensable, as with no other

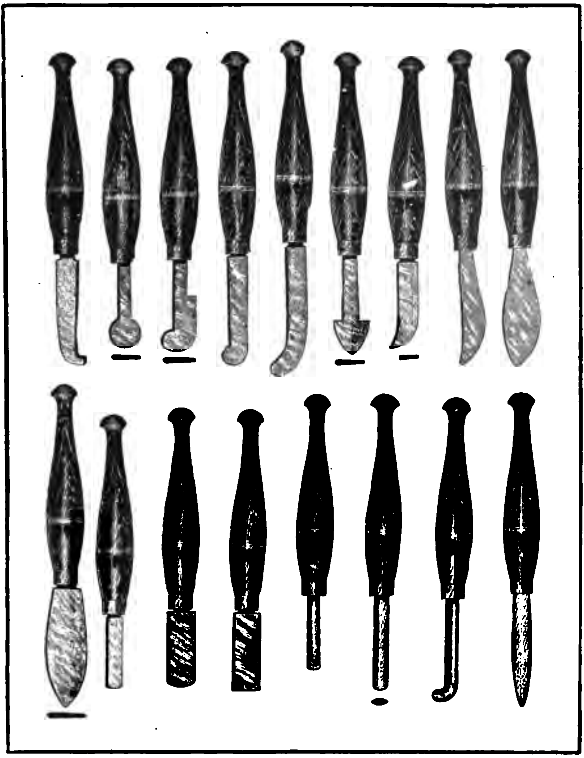

Fig. 25. Burnishing Tools.

device can the operator reach as well all sorts and conditions of metal surfaces that are inaccessible with the regular polishing wheels.

Burnishing Tools. The work of burnishing is usually performed by means of steel tools, a complete set of which are illustrated in Figure 25.

Hydrometers. These are glass instruments resembling thermometers in outward appearance, but having a large glass bulb near the bottom, as shown in Figure 26. They are used for testing the specific gravity of liquids, or, in other words, to test their density as compared with that of pure water. The liquid to be tested is placed in a narrow glass jar, Figure 27, from the flask shown in the same figure, together with the hydrometer, or may be put in any other vessel. The instrument floats in the liquid to be tested, with its bulb below the surface and its stem standing above the surface. This stem is graded in degrees similar to that of a thermometer, and shows the depth of the bulb beneath the surface. In pure water the bulb sinks down to the 0 degree mark, or to 1000 as marked on some scales, 1000 being taken to represent the density of water at a temperature of 60 degrees Fahrenheit. As the density of the water increases by the addition of salts or of liquids having a greater density than

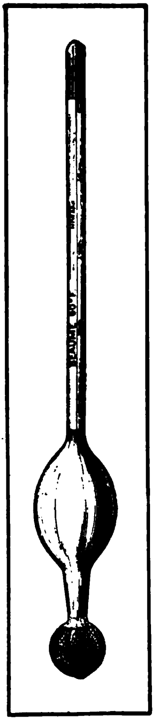

Fig. 26.
Hydrometer.

water, the bulb is forced upwards, and the scale then registers so many degrees greater density than water.

Two differently graduated hydrometers are in use in this country. These are: hydrometers graded to read direct the specific gravity of liquids in comparison with that of water, taking this as represented by 1000, and hydrometers graded by a scale adopted by M. Baumé, and called the Baumé densimeter. The difference between the two gradings is shown in the following table. In some text-books and printed instructions on this art, reference is made to testing solutions by means of a hydrometer, and certain figures are given to denote the required density of the solution. These are fallacious unless direct reference is also given to the kind of hydrometer to be used. This will be seen on reference to the following table, wherein is shown at a glance the difference between the readings of Baumé and the direct reading specific gravity hydrometers.

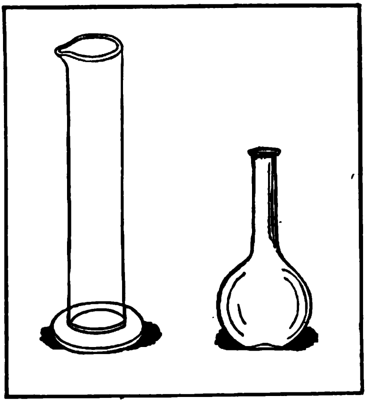

Fig. 27. Testing Jar and Flask for Use with Hydrometer.

Table Showing Readings of Different Hydrometers.

Baumé	Specific Gravity	Baumé	Specific Gravity	Baumé	Specific Gravity
10°	1.0000	37°	0.8395	64°	.7423
11°	0.9930	38°	.8346	65°	.7205
12°	.9861	39°	.8299	66°	.7168
13°	.9791	40°	.8251	67°	.7133
14°	.9722	41°	.8204	68°	.7097
15°	.9658	42°	.8157	69°	.7061
16°	.9594	43°	.8110	70°	.7025
17°	.9530	44°	.8063	71°	.6990
18°	.9466	45°	.8017	72°	.6956
19°	.9402	46°	.7971	73°	.6923
20°	.9339	47°	.7927	74°	.6889
21°	.9280	48°	.7883	75°	.6856
22°	.9222	49°	.7838	76°	.6823
23°	.9163	50°	.7794	77°	.6789
24°	.9105	51°	.7752	78°	.6756
25°	.9047	52°	.7711	79°	.6722
26°	.8989	53°	.7670	80°	.6689
27°	.8930	54°	.7628	81°	.6656
28°	.8872	55°	.7587	82°	.6619
29°	.8814	56°	.7546	83°	.6583
30°	.8755	57°	.7508	84°	.6547
31°	.8702	58°	.7470	85°	.6511
32°	.8650	59°	.7432	86°	.6481
33°	.8597	60°	.7394	87°	.6451
34°	.8544	61°	.7357	88°	.6422
35°	.8492	62°	.7319	89°	.6392
36°	.8443	63°	.7281	90°	.6363

Thermometers. In electro-gilding operations a thermometer is needed to ascertain the right temperature of the gilding solution. This instrument must be wholly of glass, as any metal-work will dissolve in the hot gilding solution. The best for this purpose are those with a white enameled scale enclosed in a glass tube. The scale may be graded in degrees, Fahrenheit or

Centigrade, as may be most convenient to the operator. If the scale is graded in Centigrade degrees, and it is desired to ascertain the value of a reading in degrees Fahrenheit, add 32 to the reading, multiply the product by 9, and divide it by 5. If the reading is in degrees Fahrenheit, multiply the reading by 5, subtract 32 from the product, and divide it by 9 to convert the reading into Centigrade degrees.

Rheostats, Use of. Rheostats are of the first importance in the plating room. Without them the varying degrees of current necessary for handling different solutions, or for manipulating baths of various sizes, cannot be obtained.

A rheostat is necessary in the field of the dynamo where it will control the voltage along the entire line of connection, enabling an initial current strength to be maintained while the tank rheostats further reduce this current to the proportions required.

The rheostat in the field, while it affects the voltage by setting a fixed resistance in the field of dynamo, does not affect the ampere capacity except in a minor degree. On the other hand the rheostat placed between the main line and the tank affects both the voltage and amperes, reducing the latter in the same proportion as the former is cut down. It is necessary, then, that the rheostat selected for the tank be of ampere carrying capacity sufficient to handle the current used in the tank. If the rheostat has not sufficient capacity to handle the ampere current a resistance is formed which prevents the proper amount of current from flowing into the tank.

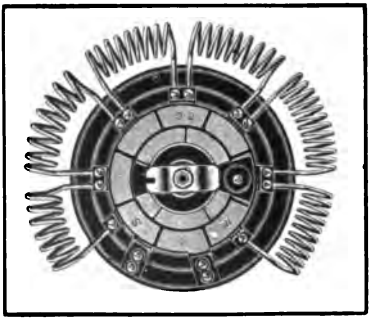
Fig. 28. Rheostat.

The action of a current of electricity can be likened to the passage of water through a pipe, the force with which the water flows from the aperture representing the voltage, while the quantity discharged may represent the ampere current. If a valve or stop-cock is placed in this pipe the action would be similar to that of the rheostat in an electric circuit.

Fig. 29. Voltmeter.

In arranging tanks it is necessary that conductors be of sufficient size to carry the greatest number of amperes the tank will handle. Different solutions require different amperes per square foot of work surface.

A plain rheostat is illustrated in Figure 28.

Voltmeters. The voltmeter shown in Figure 29 has a scale from 0 to 6 volts and upwards. The scale is divided into 120 divisions, so that each division represent one-twentieth of a volt, and when used in connection with the switch boards will enable the plater to study carefully all the requirements that insure good results, and will give the means of accurately reproducing such conditions as have been found by experience conducive to success.

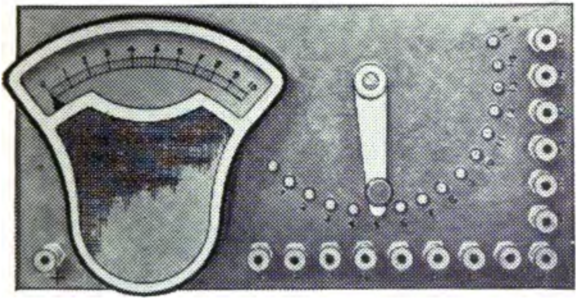

Fig. 30. Combination Voltmeter and Rheostat.

A combination of a voltmeter and a rheostat mounted on a slate base is illustrated in Figure 30.

Ammeter. It is a fundamental law of electrolysis that a certain number of amperes passing through a plating solution will cause a definite weight of metal to be deposited. As, for instance, one ampere will deposit in one hour 1.106 grammes of nickel, 4.15 grammes of silver. It is evident, therefore, that by means of an accurate ammeter, such as shown in Figure 31, the amount of metal actually deposited can easily be determined.

Time Dial. To denote the time of taking the work out of the tanks, the dials illustrated in Figure 32 will be found to be very useful. They are made very strongly of bronze, oxidized and lacquered, with nickel-plated hands, and bright figures. They are eight inches in diameter, and are quite flat, and can be screwed up or suspended over or near tanks.

Fig. 31. Ammeter.

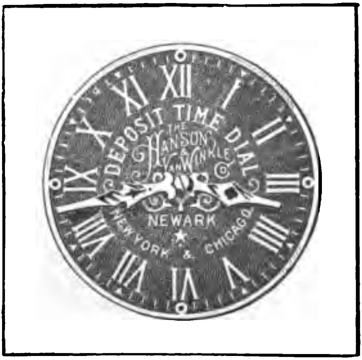

Fig. 32. Time Dial.

Respirator. Figure 33 shows one of the latest forms of respirators.

This is one of the best devices for protecting the throat and lungs from dust, poisonous gases, and all other impurities, in places where persons are exposed, and, many times, life endangered.

In respiring, the air is inhaled through a thin, wet sponge or cotton, and, in expiring, passes out through an automatic valve in the side, so that breathing with the respirator is easy, allowing it to be worn constantly, without the least inconvenience. They are manufactured of the best white rubber, and will last a lifetime. The sponge can be easily taken out, rinsed, and replaced in one minute.

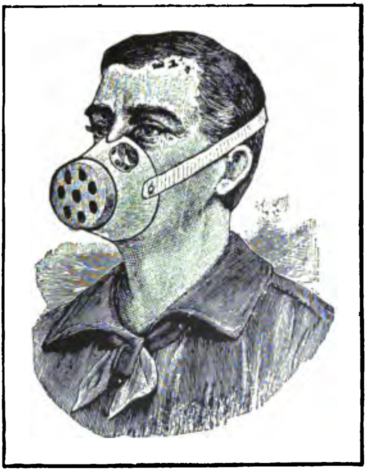

Fig. 33. Respirator.

Steam Generators. Where no outside source or supply of steam is available, the steam generator shown in Figure 34 will be found a very useful adjunct to an electro-plating plant.

The generator has a ring below, a water front beneath the fire door, and water tubes surrounding the fire and steam dome above. Cast iron shields fit in the spaces between and behind the tubes and extend around the heater from the top of the bottom ring and as high as the bottom of the fire door. These shields prevent the accumulation of ashes between the tubes. They also become hot and radiate their heat to parts of the tubes not exposed to the fire. There is an air space between them and the outer sheet steel jacket. In the smaller sizes a float and valve to automatically regulate the water supply is placed inside the steam dome, while in the larger sizes this water-regulating device is contained within an iron float box outside of the boiler, but connected to it by pipes, as shown. The safety valve is set to blow off at about 12

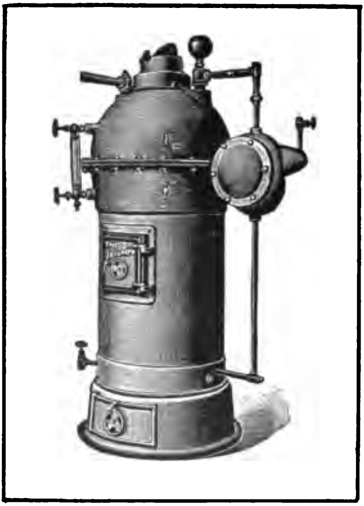

Fig. 34. Steam Generator.

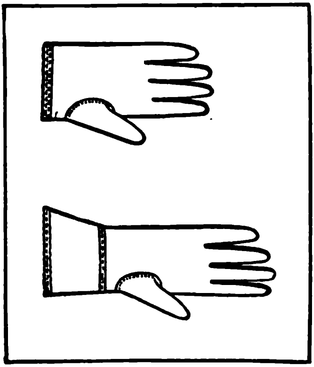

Fig. 35. Rubber Gloves.

pounds' pressure and the float has buoyancy enough to shut off the water up to about 30 pounds' pressure. In places, therefore, where there is a water works pressure of from 12 to 30 pounds or so the boiler can be attached at the float valve to a pipe from the hydrant. Where pressure is above or below this or there is no water works a supply barrel or iron supply tank can be used.

Rubber Gloves. Figure 35 shows two styles of rubber gloves for platers' use when handling chemicals, lye, acids, etc.

Finger Cots. These finger cots, which are very necessary for the protection of fingers against chemicals, and also for scratch-brush work, are shown in Figure 36.

Wooden Shoes. As water in abundance is found to be necessary for some plating and pickling operations, which keep the floors constantly wet, the shoes shown in Figures 36 are a very desirable article of wear for the plater.

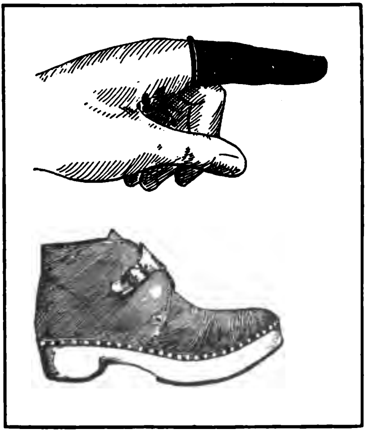

Fig. 36. Finger Cot and Wooden Shoe.

Fig. 37. Rubber Apron.

Fig. 38. Felt Filter Bag.

Rubber Aprons. Rubber aprons, which are very necessary during pickling or scouring operations, are shown in Figure 37.

Felt Bags. Felt filter bags for rapidly filtering solutions are shown in Figure 38.

Glue Pot and Brush. In small plating shops where a steam supply is not available, a glue pot and brush of the style illustrated in Figure 39 will be found very useful when it is desired to renew the abrading material on the surface of leather buffs.

Fig. 39. Glue Pot and Brush.

Rod and Wire Connectors. Connectors, as shown in Figure 40, are almost an indispensable article of a plating outfit to properly make the necessary connections between the dynamo and plating vats. Five different styles are illustrated in the drawing.

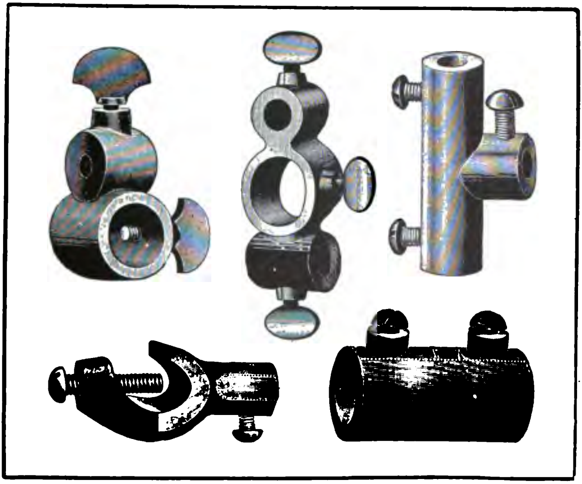

Fig. 40. Rod and Wire Connectors.

Suitable Depositing Solutions. The first consideration should be given to a selection of the best depositing solution and one suited to the purpose in hand. Select a solution that will yield up its metal freely under the influences of the electric current, but one which will not deposit its metal on articles by simple immersion in the solution. Choose a solution that will dissolve the anode freely, and thus maintain the solution in a constant working condition. These points having been observed, let the choice rest upon a solution made up in the most simple manner, out of the least number of ingredients. The solution should contain only the salts of the metal to be deposited, and these salts should break up at the cathode into deposited metal and its solvent, which should be retained in the solution. The best depositing solution for silver is one composed of the double cyanide of silver and potassium in distilled water. This solution will yield up its metal freely under the influence of a low voltage current of electricity, and the double salt breaks up at the cathode into deposited silver and potassium cyanide. As the latter is a solvent of silver when this metal forms the positive electrode in a solution of cyanide of potassium, the anode dissolves freely, and maintains the solution in working order. That is to say, it furnishes to the solution an equivalent of silver for each equivalent withdrawn. All the double cyanide salts are of general utility, forming excellent depositing solutions of gold, silver, platinum, copper, zinc, and mercury.

Metals Easily Deposited. Gold may be deposited from its solution of the double cyanide of gold and potassium in good condition under the influence of a very feeble current of electricity. Copper is also easily deposited from its solution of copper sulphate. This solution will deposit copper on zinc, iron, and steel, by simply immersing these metals in the solution, but the copper so deposited can be easily rubbed off again, as it is only a mere film obtained by chemical action on the surface of the immersed metal. The voltage needed to decompose a solution of copper sulphate may be as low as half a volt, and in most cases need not exceed one volt. Higher voltages than these are necessary to overcome resistances met with in actual practice and to effect rapid depositions of the metal. To deposit copper from its alkaline solutions, a current of higher voltage is required, varying from 5 to 10 volts according to the resistance of the work in the circuit. Silver requires a current of higher voltage to deposit it from its solution of the double cyanide of silver and potassium, than that required for gold.

Metals of Low Cost. The least costly metals are not, as a general rule, the most easy to deposit in a good condition. Iron may be placed first, as being of least cost, but it cannot be easily deposited in good condition. Zinc is also a cheap metal, but there are difficulties attending its deposition. Tin may be easily deposited, but the depositing solution needs careful attention to keep it in working order. Lead offers little of practical interest to the plater. The same may be said of bismuth and antimony. Copper is a useful metal, of moderately low cost, and one easily deposited in good condition.

Nickel, as compared with copper, is a costly metal, but it is also a very useful metal. Cobalt, the sister metal of nickel, has not come into general use, but it may be classed with that metal. Silver is the plater's metal, and a general favorite with amateur platers, as it is easily deposited.

Metals Not Easily Deposited. Although such metals as gold, copper, and silver may be easily deposited in good condition from suitable solutions when employing an electric current of low voltage, this only touches the question of comparatively easy deposition and the rapidity of the process under suitable conditions. The condition of the deposited metal is greatly affected by the tenuity or the density of the solution, and the strength of current as well as its electromotive force or voltage. Some metallic salts need a higher voltage to decompose them than others, but the main consideration must be directed to current strength rather than to voltage, since the quantity of metal deposited from a solution in a good condition in a given time will greatly

DEPOSITION BY SIMPLE IMMERSION.

SOLUTION.	Bismuth.	Brass.	Copper.	Gold.	German Silver.	Iron.	Lead.	Platinum.	Mercury.	Nickel.	Silver.	Tin.	Zinc.
Antimony Terchloride	d	d	o	n	d	o	d	n	o	n	n	d	d
Bismuth Chloride	n	n	n	n	n	d	d	n	o	o	o	d	d
Copper Sulphate	n	o	n	n	o	d	d	n	o	n	n	d	d
" Nitrate	n	o	n	n	o	d	d	n	o	n	n	d	d
" Chloride	d	o	n	n	o	d	d	o	o	n	n	d	d
" Dichloride	n	o	n	n	o	n	n	n	o	n	n	n	d
Gold Terchloride	d	d	d	n	d	d	d	d	d	d	d	d	d
" Dble. Cyanide	n	d	d	n	d	n	n	n	o	n	n	n	Q
Mercury Nitrate	d	o	d	n	o	d	d	n	o	o	n	o	d
Mercurous Salts	d	d	d	o	o	d	d	o	o	o	d	d	d
Platinum Chloride	d	d	d	n	d	d	d	n	d	d	d	d	d
Lead Nitrate " Acetate	n	n	n	n	n	n	n	n	o	n	n	n	d
Silver Nitrate	d	d	d	n	d	d	Q	n	o	d	n	Q	d
" Alcoholic Nitrate	d	d	d	o	d	n	o	o	o	o	o	d	d
" Dble. Cyanide	n	d	Q	n	d	n	Q	n	o	n	n	n	Q
Tin Chloride	n	n	n	n	n	n	d	n	o	n	n	n	d
Zinc Salts	n	n	n	n	n	n	n	n	o	n	n	n	n

depend upon the number of amperes of current we can get through the solution. The salts of nickel, zinc, tin, and iron appear to need a current of greater strength to decompose them than those of gold, silver, and copper.

Rate of Deposit of Metal. Each metal has its own peculiar qualities which govern the rate at which it can be deposited in a good condition. This condition has been named a reguline state, that is, a state nearly like that of the metal when melted and cast in a mould. Electro-deposited metal, however, is generally so porous, even in its best condition, as to be rarely air-tight and water-tight. The quality of a deposit is governed by the quality of the solution from which it was obtained, the temperature of the solution, and the quantity of electric current passing through the article to be coated, in a stated time. This last is called the density of the current, and it determines the quantity of metal which can be deposited in a given time. The following list shows the quantity of metal which can be deposited with a current density of one ampere on one-tenth of a square foot of surface in one hour.

Aluminium,	52.4977	grains.
Silver,	52.1142	"
Zinc,	18.7240	"
Copper,	18.1638	"
Gold,	37.7290	"
Nickel,	16.9030	"

CLEANING THE WORK

The term cleanliness, when applied to metal surfaces about to receive a coat of electro-deposited metal, means absolute freedom from the least trace of dust, grease, or other animal matter, rust, corrosion, or any other form of oxidized metal. As an example, a surface made clean by any mechanical means alone will not serve the purpose, because loose metal dust and minute particles of the polishing material may be left on the surface, or the cleaning material may be oily or greasy, and the particles of dirt thus left on would prevent perfect adhesion of the deposited metal. If a perfectly clean surface be handled with the naked hand, the deposited coat will strip off the spots touched with the hand. The surfaces to be plated must therefore be made clean by mechanical means, and then made chemically clean by suitable solutions of acids or of alkalies. Each metal requires a slightly different treatment to that of others.

Cleaning Cast Iron. Iron castings may be coated with copper or with brass in an alkaline bath, or with nickel or zinc, but are rarely coated with silver or with gold. The method of cleaning is the same for each process. The casting must be first freed from the hard black crust of burnt sand on its surface, and particles of sand from its pores. To do this, immerse the casting in a pickle composed of six fluid ounces of sulphuric acid to each gallon of water, and let it soak for half an hour. If, at the end of this time, the black crust has become sufficiently loose to be rubbed off with the tip of a finger, the operation of pickling is complete. If there are obstinate scales, re-immerse it in the pickle for a short time, then try the hard spots again. If they are still obstinate, pour a little muriatic acid on them and put the casting again in the pickle. When the black scale is all loosened, rinse the casting in water and take it to the scouring tray, where it must be scoured with wet silver sand and a hard brush until a clean, bright surface has been obtained. If there are any sand-holes, these must be cleaned out with a sharp steel point, and the clean, bright casting rinsed at once in clean water, then transferred without loss of time to a cold potash solution. In this it may remain for a short time whilst getting the bath ready, when it must be again rinsed in clean water, and transferred at once to the bath of copper, nickel, brass, tin, or zinc. If the casting is large, a number of stout slinging wires must be employed, as cast iron itself is an inferior conductor of electricity. If the casting is greasy, or has been used where oil could get on it, the casting must be put in a hot potash dip, scoured, and rinsed before placing in the acid pickle. If it is rusty, the rust spots should be smeared with muriatic acid before being placed in the pickle.

Cleaning Wrought Iron or Steel. Wrought iron should be treated in a similar manner to cast iron, the pickle being the same for both, but it will not be necessary to leave the articles so long in the pickle before scouring them. As a high polish may be desired on wrought iron and steel articles, this is given to them on the polishing lathe by means of emery wheels, and bobs charged with sand, lime, emery, rough cut tripoli, and other abrading substances, to first grind down all roughness, then finish with crocus powder on a leather mop, or with the crocus powder on a circular bristle brush. After being thus brought to a high state of polish they should be passed through the potash dip to free them from the grease contracted in polishing, rinsed in water, and brushed with a soft brush free from grease, then transferred at once to the plating vat. Should there be any delay in finishing the polished steel, or should the article be large, its surface will be sure to contract a slight film of rust, and this must be removed by dipping each article for a few moments in a pickle composed of eight fluid ounces of muriatic acid in each gallon of water, then rinsing in water and transferring at once to the plating bath. Celerity in finishing wrought iron and steel is necessary, because of the tendency of these metals to rust when wet and exposed to the air. The slightest film of rust, not to be detected by the eye, will be sufficient to cause a loose deposit which will strip whilst being finished or burnished.

Cleaning Copper, Brass, and German Silver. As brass and German silver are alloys of copper with zinc and nickel, they may be conveniently classed together for preparatory treatment, this being the same for all of them. There are several other alloys of copper with zinc, nickel, tin, aluminium, and iron, but to the plater they are all brass, and are to be treated in a similar manner in preparing them for plating. It must be distinctly understood beforehand that defects in the surfaces of metals cannot be covered up by depositing upon them a coat of another metal. If the surface of the article is scored with scratches, or pitted with corrosion, the scratches and pits, however small, will appear on the plated surface, and cannot afterwards be effectually removed by subsequent polishing and burnishing. Even when the surface has been highly polished, if it should be accidentally marred by a stain, the dull, irregular spot will appear on the plated surface and mar its appearance. This fact points to the necessity of care being taken in removing all scratches and other roughness from the surface by a series of polishings, beginning with rough cutting materials on bobs and buffs made of bull-neck, walrus, and leather, felt, etc., and finishing off with the finer abrading materials on calico and swansdown mops. In large establishments this work is done in the polishing room by men who devote their whole time to this branch of the business, and the polished articles are handed into the plating room on shallow wooden trays. As they leave the hands of the polisher their surfaces have a bright, lustrous appearance, and it would appear to the uninitiated that it would be only necessary to wire the goods and hang them at once in the plating vat, so clean and bright do they appear. As a fact, the smooth, bright surface left by the polisher is covered by a slight film of grease left from the polishing materials, and this must be removed by soaking the goods in a hot potash dip. They must therefore be connected to lengths of wire and suspended in the hot potash solution until wanted at the scouring trough. After the film of grease has been removed in the potash dip, the articles are taken one at a time to the scouring trough and laid on a transverse shelf of wood, whilst briskly brushed with hogs' bristle brushes dipped in finely-powdered pumice stone, or with a mixture of equal parts pumice and rotten stone. This is done to clear off the last remaining trace of animal matter, and also to impart a slight uniform roughness to the surface, such being necessary to insure perfect adhesion of the deposited coat of metal. To insure this, it is not necessary to scour the surface hard, but to merely brush it briskly to and fro with a wet brush charged with the scouring powder, care being taken to keep the brush well charged with the powder. The brush to be used for this purpose must be free from grease, but should the presence of grease or oil be suspected, it will be well to take the precaution of dipping the hairs for an instant in the potash solution and rinsing the brush in water before using it. The scouring trough should be divided into two parts, one division being used for scouring and the other containing water for rinsing the scoured articles. The powdered pumice is held in a box fixed to the inside edge of the scouring division, furthest from the workman, who first dips his brush in the water and shakes out the surplus, then dips it in the box of powder, some of which adheres to the wet hair. This process is repeated as the powder wears off, and, when the article is properly scoured, it is rinsed in the water contained in the rinsing division, wired with the necessary slinging wires, dipped in the final dipping solution, again rinsed in clean water and suspended at once in the plating solution.

While German silver, brass, and some other alloys of copper are being scoured, they contract a slight film of oxide. If the cleaned articles are to be nickel-plated, this film is removed by dipping in a solution of cyanide of potassium in water, called a cyanide dip, and this is the final dip before placing the goods in the plating vat. If the goods are to be silver-plated, they should receive a final dip in a dilute solution of nitrate of mercury, which coats the surface with a thin film of mercury. This process, named quickening, is adopted to remove the film of oxide already noticed, and to replace it with a film of clean metal to which the silver can closely adhere. It is sometimes used in preparing articles to be gilded, but quickening is not always necessary to perfect adherence of silver or of gold. If the gilding or plating solutions are properly prepared, and the scouring operations conducted with sufficient celerity and care, a perfect adherence of the gold or silver coat can be secured by swilling the article in a cyanide dip, as for nickel-plating, or by merely moving it to and fro in the plating bath for a few moments before connecting the slinging wires to the cathode rod.

Cleaning Old Articles. Much of the plater's time in jobbing shops will be taken up in plating old articles, or in re-plating those that have formerly been coated with tin, zinc, nickel, silver, brass, or gold. The first consideration should be paid to the nature of the old plated coat, with a view to adopting the proper means for its complete removal, since successful re-plating of articles coated with patches of metal cannot be done. As old articles are generally more or less discolored by tarnish and dirt, this coat must be first removed by boiling in potash solution and brushing with the scratch-brush. Gold may be distinguished from brass by dropping on the coat from the tip of a glass rod a single drop of nitric acid. This acid will immediately dissolve the brass and cause a green spot, but on gold it will not have any effect. Silver may be distinguished from nickel or from German silver by dropping on the coat a mixture of 6 parts nitric acid and 1 part chromic acid, to which has been added 2 parts of water, or 2 parts strong bichromate of potash solution instead of chromic acid. If silver is present, it will be indicated by a blood-red spot where the mixture attacks the metal, while a greenish spot will reveal the presence of German silver or of nickel. Tin and zinc will freely dissolve in a mixture of muriatic acid and water, but this will have no effect on silver and very little effect on nickel. When the outer coat of grease, dirt or plated metal has been removed, the surface will be seen to be pitted, scratched and otherwise worn. These marks must be removed on the polishing lathe or by hand if the re-plated article is to have a finished appearance, unless in so doing the metal is worn too thin to be of any use. When the surface is thus polished, it must be further treated as new work to be plated. It sometimes happens that old goods are made up in pieces put together with soft solder. These soldered joints will clearly appear after the dirt and outer coats have been removed, and are likely to cause trouble if not discovered and properly treated before placing the goods in the plating vat. Soldered joints must be coated with copper in the following manner after the article has been scoured. A small glue brush or paint brush must first have some fine iron wires twined among its hairs, which must then be dipped in a strong solution of sulphate of copper and drawn along the soldered seam. This will cause a thin film of copper to be deposited on the solder, and this film will readily take the mercury from the quickening solution. If there are large patches of solder or lead mounts on the article, it will be best to coat the whole article with copper or with brass in an alkaline coppering or brassing solution before attempting to plate it with silver, gold, or nickel. If old cruet-stands are made up of two or more different kinds of metals or their alloys soldered together, these must be unsoldered and the different parts treated apart, or the whole must be coated with copper in an alkaline copper bath before plating. It sometimes happens that articles are made up of tinned iron bottoms, cast pewter legs and sides soldered together, German silver or brass wires and steps, and pewter knob or loop at the top. These parts may be detected by scraping some obscure spot with an old knife or a file. As such dissimilar metals will not plate together in the bath at the same time, because they form galvanic pairs in the solution, we must either separate them by unsoldering, and plate them separately, soldering them together again afterwards, or give the whole a coat of copper under a vigorous current, then quicken with mercury and re-plate without loss of time.

Cleaning Work by Hand. The use of machinery for polishing metals has, to a certain extent, superseded the old practice of preparing and finishing the articles by hand. As a large quantity of good work has been frequently done by hand in the past, the same quality of work may still be turned out in small shops, where all the scouring, polishing and brushing must be done by hand. The first thing to be done is to remove all dirt and corrosion. This is effected by means of the acid and other dips, combined with alternate brushings with coarse bristle and wire brushes in the scouring trough. Next is the removal of all corrosion pits, scratches and other damages to the surface. The first part of the process is done with lumps of pumice stone previously faced by rubbing on a flat stone. With these prepared lumps dipped in water, all the corroded and scratched parts of the surface are gone over, grinding them down until they are almost obliterated, then the entire surface is gone over in a similar manner to produce a uniform effect. This done, well rinse the article and dry it. When dry, go over all the surface with a piece of fine emery cloth placed over a bung, and rub out the scratches made by the stoning process. Scour off all traces of emery with a soft hair brush in water, well rinse the surface and go all over it with rotten stone to rub out all the scratches made by the emery. The stone must be frequently dipped in water and rubbed in one direction, going over all the surface until it appears quite smooth. When this has been accomplished, the surface may be finished with a piece of buff leather smeared with fine cut crocus, fine cut tripoli, or rotten stone and oil, the leather being glued to a stick or held over a bung. The polished surface may now be scoured and prepared for plating.

Polishing Jewelry. Such articles as studs, sleeve links, solitaires, buttons, earrings, finger rings and small brooches become tedious to polish when a large number of them have to be done by hand at one time. In factories where a large number of such things have to be polished, they are all put together in a rumble, that is, a barrel revolved by machinery, and polished by friction against each other. This may be imitated by hand, using a canvas sack instead of a barrel. The small goods are placed in a long canvas bag with some dry sawdust, and well shaken by two persons, one at each end, or one end may be tied to a post and the other shaken up and down until the small goods are polished.

DIPS AND DIPPING

When articles are in a good state of polish as regards the mere smoothness of the surface, but are coated with a film of oxidized metal, that is, tarnished, and are also free from animal matter, such as grease, the required condition of surface for plating may be imparted by dipping them in an acid solution and then swilling them in an abundance of clean water. This process is called dipping, and the acid solutions are known as dips. Copper, brass, German silver, and all copper alloys, may be dipped in commercial nitric acid, or in a mixture composed of nitric acid, 2 pints—sulphuric acid, 4 pints—water, 1 gallon. If this does not work well on bronze, German silver, and yellow brass, add a little hydrochloric acid, say one fluid ounce at a time, until the desired effect has been obtained.

Potash and Cyanide Dips. To free the surfaces of metal from grease left by the polishing processes, it is necessary to steep the articles in a hot potash dip made by dissolving half a pound of caustic potash or Babbit's potash in each gallon of water employed. This solution should be kept in a wrought-iron tank or pot, with means provided for keeping it hot. As its solvent power is impaired quickly by contact with air, it should be covered up when not in use, and as its caustic properties are neutralized by the grease dissolved off the articles, the solution must be kept in working order by frequent renewals. Care must be taken in handling the material and its solutions, as it has a powerful caustic action on the skin. Cyanide dips are employed to dissolve slight traces of oxide from the surfaces of goods prepared for nickel-plating. The dip is prepared by dissolving half a pound of commercial cyanide of potassium in each gallon of water contained in a stoneware vessel. This dip is used cold.

Iron Pickle. A pickle for iron is made by mixing in a stone jar or tank, according to quantity, the following solution: Sulphuric acid 1 part, water 15 parts. Muriatic acid may be substituted for the sulphuric if desired.

Bright Dip for Iron. A dip which leaves the surface of the metal bright is made by mixing slowly in the following order: Water 240 parts, sulphuric acid 28 parts, zinc 2 parts, nitric acid 12 parts.

Copper, Brass and Bronze Pickle. The castings should be pickled in dilute muriatic acid to remove the scale, and then cleaned and brightened by dipping in a solution made up as follows: Sulphuric acid 50 parts, nitric acid 100 parts, common salt 1 part, lamp black 1 part.

Bright Dip for Copper or Brass. Copper or brass work that is not to be buffed or polished should be first dipped in a pickle of nitric acid 200 parts, common salt 1 part, lamp black 2 parts.

After pickling until clean, they should be thoroughly rinsed in boiling water, allowed to dry for a moment and then plunged into the following solution: Nitric acid 75 parts, sulphuric acid 100 parts, common salt 1 part.

Cyanide Dip for Brass. Cyanide of potassium in ten times its weight of water should be used as a preliminary dip when plating articles that would otherwise have the polish injured by the acid dips. The work must be allowed to remain longer in this than in the acid solution.

Pickle for German Silver. German silver may be cleaned in the bright dip for copper or brass, or in a preliminary pickle of dilute nitric acid and water, 1 part of nitric acid to 12 parts of water, followed by a dip in equal parts of sulphuric and nitric acids to 24 parts of water, and then rinsing in boiling water and drying in sawdust.

STRIPPING

This term is employed to denote not only an accidental loosening of the deposited metal under the scratch brush or the burnisher, but also a purposed loosening of a deposit by means of acid solutions. Silver is stripped from old plated work on copper and its alloys, before they can be re-plated, by immersing the plated article in hot and strong sulphuric acid, and adding from time to time a few crystals of saltpeter. The acid must be made hot, the articles to be stripped must be quite dry before immersing them in the acid, and must be moved about while adding the saltpeter. If this is done as directed, the whole coat of silver may be loosened without serious damage to the metal beneath. The same operation may be performed in a cold mixture, composed of 1 part strong nitric acid added to 10 parts of sulphuric acid in a stoneware vessel. The goods to be stripped in these acids should be first attached to stout wires, as they must be frequently moved about in the solution, and taken out to be examined from time to time, to prevent overdoing the process and injuring the metal beneath the coat. When all the silver has been stripped off, the article must be at once rinsed in clean water to free it from acid; but should it be necessary to re-immerse the article, it must be first dried, since the presence of water in the acid will cause it to attack the metal beneath the coat of silver. When the plated article is made of iron, steel, zinc, pewter, lead, or white metal, it must not be immersed in the stripping acid, but should be desilvered in a solution of cyanide of potassium by means of a current from a battery or a dynamo. An old disused plating solution will do very well for this purpose if it has plenty of free cyanide. Immerse the article to be stripped, and connect it as an anode to the positive pole of the battery or dynamo, and suspend a plate of carbon or a strip of platinum foil in the solution as a cathode. Then pass a strong current until all the deposited coat of silver has been dissolved. Gold may be removed from gilded articles by a similar method in an old gilding solution. The gilt insides of cups and mugs can be removed by filling them with the cyanide solution, connecting them to the positive pole of the battery and passing a strong current from them to platinum cathodes suspended in the solution without touching the sides of the vessels. Gold may also be stripped from base metals by immersing them in hot nitric acid and adding some common salt as required. This operation is similar to the acid process for stripping silver, and needs equal care. Nickel is stripped from nickel-plated articles in a mixture composed of 1 pint of water, 1 pint of strong nitric acid, and 4 pints of strong sulphuric acid. The water must be first placed in a lead-lined vessel, or in one of enameled iron, and the sulphuric acid added gradually and carefully, as the addition of this acid to water raises its temperature to a boiling point. When the sulphuric acid has been mixed with the water, the mixture must be poured into a stoneware dipping pan and the nitric acid added. These precautions are necessary, because the mixture of the two acids and water will dissolve lead and enamel, but will not pierce acid-proof stoneware, whilst this in turn will not stand sudden expansion caused by the heat generated in mixing the sulphuric acid with water. Whenever this acid is to be mixed with water, the acid must be poured slowly into the water, instead of mixing them by pouring water into acid. All operations in stripping by acids must be performed in the open air, or under conditions similar to those laid down for dipping processes. The process must be closely watched throughout, and the article removed from the stripping solution immediately its coat of metal has been stripped off. The time taken up in this operation may be only a few minutes if the coat is thin, or it may extend to half an hour, or even more when thick coats have to be stripped.

Cleaning Zinc. Some highly artistic and ornamental articles in cast zinc have the appearance of solid silver and solid gold imparted to them by electro-plating. Zinc goods of all kinds should be first immersed for a few minutes in a hot potash solution to free the surface from any trace of grease, then well rinsed and immersed in a pickle composed of sixteen fluid ounces of sulphuric acid to each gallon of water for a few minutes, then rinsed to free the surface from acid and passed on to the scouring trough. Here they must be dealt with at once and scoured with a stiff brush charged with wet silver sand until the surface has been made uniformly bright, then rinsed in water and transferred to a brassing or alkaline copper bath rich in metal. The current should be strong enough to coat the article with brass or with copper in a few seconds, to prevent the surface from being blackened by the solution. When a film of copper or of brass has gone all over the surface, the anode should be raised and deposition allowed to go on more slowly. If the article has been made up in pieces put together with soft solder, or if the zinc casting has been doctored with solder, the soldered seams or patches may not at first receive a deposit of copper or of brass, but will appear black after the rest of the surface has been coated. In this case the article must be taken out, the black spots well scratch-brushed, rinsed with water, and placed again in the brassing or coppering bath with the defective spots close to the anode. By carefully moving the goods so as to bring the anode close to the defective spots in turn, they may be soon coated with metal. After the zinc has been thus coated with brass or with copper, it may be made to receive an adherent coat of gold or silver, and should be transferred directly from the brassing or coppering solutions to the gilding or plating solutions. If the finished gilded surface is to be bright, the article should go direct from the brassing to the gilding solution, but if some parts are to appear dead and others bright, the brassed zinc must be placed in a silvering solution until it gets a dead white coat of silver, then rinsed, and the intended bright parts scratch-brushed and burnished before placing in the gilding bath.

Cleaning White Metal and Pewter. These alloys of lead and tin, as well as the metals of which they are composed, require a special course of treatment to fit them for receiving an adherent coat of silver or of gold. The oxides of these metals and their alloys are soluble in hot caustic alkali solution. It is only necessary to immerse them in a hot solution of caustic potash to loosen any dirt or corrosion, brush the surface clean and bright, rinse again in a caustic potash solution, and transfer at once to the silver-plating vat. If they are to be coated with gold or with nickel, they should be transferred to a hot brassing or coppering bath and receive a coat of brass or of copper before placing them in the gold or the nickel bath.

Cleaning Silver and Gold. Tarnish on silver may be loosened by immersing the article in a hot solution of cyanide of potassium. Discolored gold may be cleaned in a similar manner. Strong warm carbonate of ammonia solution will also loosen the tarnish on silver. After being thus loosened, the tarnish must be removed by brushing and scouring, or by means of a scratch brush.

A special form of brush is used to prepare the insides of silver vessels about to be electro-gilt. Filigree work, and similar delicately formed articles in gold and silver, should be first heated on a jeweler's warming pan before plunging them in the hot cyanide solution, as this class of goods cannot be cleaned by brushing or scouring. The articles to be cleaned should be covered with slices of lemon in a vessel for several hours. They are then rinsed in water, boiled in soapsuds, again rinsed, and finally dried on a hot-water bath. Silver may also be cleaned by boiling in potato water.

Clearing off Corrosion and Rust. Corroded copper, brass, German silver, and similar alloys, must be first immersed in a pickle composed of sulphuric acid 3 pints, nitric acid 1¾ pints, water 4 pints. This will loosen and dissolve the corrosion. Corroded zinc should be immersed in a pickle composed of sulphuric acid 1 fluid ounce, hydrochloric acid 2 fluid ounces, water 1 gallon. Rusty iron or steel should be first pickled in a solution composed of sulphuric acid 6 fluid ounces, hydrochloric acid 1 fluid ounce, water 1 gallon. When the rust has been removed, immerse the iron or steel in a pickle composed of sulphuric acid 1 pint, added to 1 gallon of water in which one-quarter of a pound of zinc sulphate has been previously dissolved. Dirty lead, pewter, white metal, and tin, may be cleaned in a hot solution of caustic potash or caustic soda.

ELECTRO-PLATING WITH NICKEL

Nickel is deposited from its solutions at the rate of .004641 grains per ampere second, or at the rate of 16.756 grains per ampere hour on one-tenth of a square foot of surface.

The thickness of a nickel deposit may be ascertained by noting the strength of current employed and the exact surface of metal coated with nickel in a given time, then, knowing that 1 square foot of nickel 1,000th of an inch in thickness weighs 319.752 grains, the thickness of the whole deposit, together with its weight, may be found by calculation.

Voltage Required to Deposit Nickel. To break up the nickel salt in solution and deposit the metal in good condition on an article when first placed in the bath will require an electromotive force of from 5 to 6 volts, or that furnished by from 3 to 4 battery cells in series. If a plating dynamo does not give the necessary voltage to deposit nickel in good condition, it may be made to do so by driving it at a higher rate of speed. As a rule, there should be a flow of hydrogen gas observable from the article being nickeled, but this may be excessive. Therefore the voltage and strength of the current must be regulated until the best results have been obtained by experience. When the articles have been covered with a thin film of this metal, the intensity of the current may be reduced, and deposition allowed to go on more slowly, to insure a tough deposit. The intensity of one cell may then be found sufficient for the purpose.

Finishing Nickel Plating. Nickel deposits differ from those of silver in appearance and hardness, and must receive different treatment. Deposition must go on from the start to the finish without interruption. We may not remove the article to see how the deposit will stand brushing, as in the case of silver; if this is done the next layer will be likely to strip from the first. The deposit of nickel may not be white or brilliant, but of a dull yellowish appearance when it leaves the vat. It must then be well rinsed in hot water and dried, then passed over to the finisher, who changes the dull yellow surface to the brilliant polish desired by brushing the deposit with mops and dollies charged with lime. This is best done on the polishing lathe, with circular mops and dollies made of felt, calico and swansdown, the final finishing polish being imparted with a very soft clean mop. The articles should then be brushed with a soft brush to remove all traces of lime left in crevices on the article, and wiped with chamois leather. Nickel deposits should not be scratch-brushed with brass scratch-brushes, because the brass will wear off the brushes, and become embedded in the harder nickel deposit, causing it to have a brassy appearance. If there should be any faulty spot from which the coat strips while being finished, it may be remedied by applying a small strip of nickel anode bound up in a rag pad dipped in the nickel solution and connected by a wire with the battery or dynamo. Rest this pad on the well-cleaned bare spot, connect a wire from the negative pole of the battery to the article, and pass a current from the pad to the article until the bare spot has been coated with nickel. Experienced platers and finishers can so work this between them as to successfully patch up a spot and render it indistinguishable from the rest of the article, thus avoiding the necessity of having the work re-nickeled. This will do for small faults discovered in finishing, but when the coat strips off in large patches, or in several such patches, the whole coat should be stripped and the whole work of preparation gone over again as at the first.

Care of Nickel Baths. Nickel baths should be as carefully guarded against contamination with dirt and impurities as those of silver. The anodes should be always left in the bath, but the connecting wires and the sides of the vat should be frequently cleansed from the nickel salts which creep out of the solution and crystallize upon them. When the solution gets contaminated with dirt, and this interferes with the cleanly working of the bath, it should be filtered through a calico filter. If the metal is withdrawn from the bath faster than its equivalent is dissolved from the anodes, the solution will become acid, and this acidity must be neutralized by adding liquid ammonia to the solution in small quantities at a time, while stirring, until it ceases to redden blue litmus paper. When the solution becomes too dirty to be used, or is otherwise spoiled, all the nickel may be recovered as a double salt of nickel by adding to it a saturated solution of ammonium sulphate until the double salt falls and the solution loses its green color. The crystals thus obtained may be dissolved in hot water, the solution filtered and purified by crystallization to form a new bath.

If an old nickel solution fails to give a satisfactory deposit of metal, it may be improved by adding some common salt to the extent of from 1 to 10 per cent of the nickel salt in solution. The addition of common salt increases the conductivity of the solution, and gives a whiter deposit of nickel than that obtained from an impure solution of double sulphate of nickel and ammonia.

If a nickel solution becomes too alkaline, as shown by a yellow deposit, and its power to turn red litmus paper to blue, add sulphuric acid until it shows a slightly acid reaction.

Nickel-plating Cycle Fittings. It is not necessary to coat cycle fittings with copper previous to coating them with nickel, but it is advisable to do so for several reasons. A coat of copper will adhere firmly to iron and steel and other metals if these are properly prepared, and will show defects in the preparation, readily, by not coating the defective parts. These defects can be at once remedied without loss of time and nickel.

Nickel will also firmly adhere to copper, and the two together form a better protecting coat than that of nickel alone. Some platers not only deposit a good coat of copper on high class work, but also polish this, and re-copper the surface before depositing nickel on the fittings. Whichever method is adopted, it must be borne in mind that success not only depends on a good coat of copper, but also on absolute cleanliness in the preparation, for only a touch with the bare hand on the prepared article will cause the nickel to strip from the spot whilst being polished. In a good coppering solution a sufficiently durable coat of copper should be obtained in from fifteen to twenty minutes.

Re-plating Old Cycle Fittings. Much of the work of a cycle plater consists of old fittings sent to be re-plated. All of the old nickel must be stripped from these, to get surfaces capable of adhering firmly to the new coat. This is best done on the polishing lathe, as in preparing new fittings. First wipe off all excess of dirt, grease or oil with a rag or cotton waste, then give the fittings to the polisher. Rusty fittings must receive similar treatment. Old nickel may be removed from copper and brass fittings by stripping in acid. They must then be rinsed, dried and turned over to the polisher to be prepared. Old tinned fittings are scarcely worth the labor and expense of being re-nickeled, as they rarely look well after being stripped of their coat of nickel and tin.

Working Nickel Solutions. Nickel solutions work best in large volumes of from 100 gallons upward, and these are contained in large tanks constructed to suit the work to be done in them. For instance, if long pieces of iron and steel, such as the shafting of machines or harness chains, have to be nickeled, the nickel solution may be contained in a long, narrow and shallow trough. If sheets of iron or such articles as stove-fronts form the bulk of the business, a thin and deep vat will be preferable. In such a vat a large number of small articles strung together on wires may be nickeled, such as screws or bicycle spokes, which can be wired by taking a turn of a long wire around each screw head, and thus making a long string of them.

Double Salts of Nickel. The most important double salt of nickel is that of the double sulphate of nickel and ammonium. To prepare this, first make up a mixture of 1 part sulphuric acid, 2 parts distilled water, and one-third part of nitric acid. Make this warm in a stoneware vessel on a fire furnished with a good flue to carry off the nitrous fumes, and add pure nickel until the acid ceases to dissolve any more of the metal. Drive off the excess acid, if any remains, by boiling the solution for a short time, dilute it with one-fourth its bulk of boiling water, and set aside to cool. When cool enough to filter, pass it through a linen filter into a vessel capable of holding double the bulk of liquid. Next dissolve some sulphate of ammonium in hot water until it will not take up any of the ammonium salt, and set it aside to cool. Add the cold ammonium sulphate solution to the cold nickel sulphate solution while stirring, until the nickel solution loses all its color and a copious precipitate of the double sulphate of nickel and ammonium has been thrown down to the bottom of the vessel. Pour off the supernatant liquid, and wash the crystals with a little more of the ammonium solution. The crystals may now be dissolved in hot water and filtered. The resulting solution may be employed as the nickel bath, or may be evaporated down and set aside to cool, when the double salt will crystallize out.

TABLE SHOWING RATE OF NICKEL DEPOSITION.

Amperes of Current.	Square Feet of Surface.	Grains per Hour	Grains per 10 Hours	Lbs.	Ozs.	Drms.
1	.1	16.756	167.56	0	0	6
2	.2	33.512	335.12	0	0	12
3	.3	50.268	502.68	0	1	2
4	.4	67.024	670.24	0	1	8
5	.5	83.780	837.80	0	1	14
6	.6	100.536	1005.36	0	2	4
7	.7	117.292	1172.92	0	2	10
8	.8	134.048	1340.48	0	3	1
9	.9	150.804	1508.04	0	3	7
10	1.0	167.560	1675.60	0	3	12
20	2.0	335.120	3351.20	0	7	10
30	3.0	502.680	5026.80	0	11	7
40	4.0	670.240	6702.40	0	15	5
50	5.0	837.800	8378.00	1	3	2
60	6.0	1005.360	10053.60	1	6	15
70	7.0	1172.920	11729.20	1	10	13
80	8.0	1340.480	13404.80	1	14	10
90	9.0	1508.040	15080.40	2	2	7
100	10.0	1675.600	16756.00	2	6	4

Black Nickel-plating. It is possible to deposit a coating of nickel which will be a deep velvety black and equally as hard and as thick as the ordinary nickel plating. The solution to produce this result is as follows: Double sulphate of nickel acid 12 parts, aqua ammonia 16 parts, carbonate of ammonia 2 parts, arsenic 2 parts, cyanide of potassium (quantum sufficit) and sufficient water to make one gallon of solution. The water should not be added until all the chemicals are thoroughly dissolved.

Boracic Acid. This is of use when the nickel-plating solution becomes muddy and dense, from becoming alkaline, so that the deposit is no longer white and tough. The acid should be used in the proportion of two ounces to the gallon of solution, and has the effect of clearing up the solution and whitening the deposit.

ELECTRO-PLATING WITH SILVER

To clean the work before plating, dissolve two ounces of lye to each gallon of boiling water, and dip the articles in hot, then scrub with a hard brush and fine powdered pumice stone, or powdered bath brick, or powdered Vienna lime, then wash in clean hot water, then in cold water. If the water adheres evenly all over, it is ready to plate, if it does not, then repeat the cleaning and scrubbing.

After getting a slight coat of silver on the article it can be removed from the solution and scratch-brushed with the revolving scratch-brush, on which should be allowed to drip a little stale beer or soap suds, this lays down the grain of the silver, after which wash in clean hot and then cold water, and plate again. When sufficiently plated it can be scratch-brushed and buffed with the cotton flannel wheel, to which is applied a little powdered gold rouge mixed with alcohol into a paste. This gives the high color which takes the place of the more expensive hand burnishing. For plating silver on articles of iron or steel, it is well to give the articles a slight coat of copper from a cyanide of copper solution, which is very inexpensive. Another plan is to take, say 1 quart of silver solution, when ready for use, and add 3 quarts of water to it and 6 ounces of

C. P. Cyanide of potash. Put in a large surface of silver and only a small surface of work at a time. The article will give off gas freely from this solution, before which it should be thoroughly cleaned and pumiced, and a yellowish coat of silver will be deposited, which is very adhesive. From this put it in the regular silver solution to plate slowly until a sufficient deposit is obtained. From the work in the regular silver solution no gas should escape, otherwise a sandy, hard deposit will be the result. This can be regulated by the amount of anode immersed, distance between the anode and the work being plated, and the size of the wire, which can be reduced until sufficient resistance is introduced to prevent the escape of gas.

Silver-plated Articles, Finishing of. When the articles have received a sufficiently thick deposit of silver, disconnect each from the connecting rod, one at a time, swill them in the plating solution for a moment, drain off the solution taken by them from the bath, rinse each article well in clean hot water, and place at once in clean hot box-wood sawdust to dry. In this they should dry quite white. If they dry yellow or spotty, the cause may be traced to imperfect rinsing, or the use of soiled sawdust. When they are dry they should be taken to the scratch-brush and brushed until all the white burr or matt has been worked down. The brushes must not be worked dry, or they will stain the silver with brass, but must be kept wet with stale beer. This is best applied by means of a small drip-cock over the brush, attached to a lead pipe leading to a small cistern of stale beer placed over the lathe. Very little will be required to keep the brush moist, and the drips may be used over again if caught in a tray beneath the brush. The brush should either be made to revolve away from the work, or from left to right, to prevent splashing of the beer and snatching of the work out of the operator's hands by the brush. Only a very moderate pressure is required on the article to get its surface well brushed, slightly more pressure being necessary to force the wires of the brush into crevices. The brushes, as they come from the maker, are usually very stiff and the ends of the wires very sharp. In this condition they are apt to tear off some of the silver when first used. It is therefore advisable to break down the points by holding a piece of steel or cast iron to the revolving brush for a few minutes before using it on the silver-plated article. This wears down the sharpness of the freshly cut ends, and breaks the brush into a working condition. Brushes should, however, be selected to suit the class of work being done, the softer wires for thin coated goods and stiffer wires for more heavily coated and larger articles. When the articles have been scratch-brushed, they must be rinsed in clean water and again dried in sawdust preparatory to the next operations of polishing or burnishing.

Polishing Silver Plate and Silver. The degree of brightness or luster imparted to the surface of silver-plated articles is insured by the number of processes through which it passes. A dull whiteness is left on the surface after scratch-brushing. A better finish is given by the process of polishing. This is usually done on a polishing lathe, with similar buffs, bobs and circular-brushes to those employed in polishing the metal before plating. The lathe may be driven by foot power. A good lathe for this purpose is shown in Figure 17.

Silver-plating Solutions. Never add anything to the solution except distilled water and cyanide of potassium when required. If the solution is too rich in silver for a given purpose, take out some of it and dilute the rest with distilled water. If it is not rich enough, do not add any other salt of silver except silver cyanide. Keep the solution covered up when not in use, to keep out dust and insects, and filter it through a filter made of well-washed linen. Shade the solution from direct sunlight, as this decomposes some of the silver salt and wastes the solution. Keep it as near as possible to a regular metal pitch, that is, with an approved quantity of silver in each gallon of solution, by working it with a sufficient anode surface and a sufficient quantity of free cyanide to dissolve the anodes freely. When the anode surface exposed to the action of the solution exceeds slightly the surface of goods to be plated, and the solution contains a sufficient quantity of free cyanide, the current will dissolve from the anode as much silver as it deposits on the articles being plated. If, however, the contrary conditions are present, the solution will be gradually impoverished, and the deposit show, sooner or later, the bad effects. It is quite possible to err on the contrary side, and get a solution too rich in silver from having too much free cyanide, or exposing too much anode surface to the solution. A lack of free cyanide is shown when the anode plates assume a hard, close-grained appearance, and are more or less coated with a dark, slimy deposit of silver oxide. An excess of free cyanide is shown on the anodes by their very white frosted surfaces being pitted and their edges ragged. It is also shown on the deposit by a soft, loosely deposited coat which strips under the scratch-brush and the burnisher. The odor of cyanide is also strongly pronounced, and this is mingled with an odor of ammonia in hot weather if much work is being done. In adding free cyanide, it is best to dissolve it in distilled water and filter the solution into the bath to remove any loose dirt held in the cyanide of potassium.

Never swill freshly cleaned articles in the plating solution, nor allow them to remain in the solution unless they form part of the plating circuit and are receiving a deposit of silver, because the free cyanide will dissolve copper, brass, and other metals, and thus contaminate the solution with base metal. Solutions thus contaminated will not yield a pure white deposit of silver. Owing to such a large bulk of liquid being contained in a wooden vat, its temperature canno be regulated, but the best results are obtained between 50 and 60 degrees Fahrenheit.

Character of Silver Deposit. Electro-deposited silver is pure, if the silver employed in making up the solution is pure and the anodes are also pure. As the articles leave the solution coated with silver, their surfaces appear to have been whitewashed. The coat of pure silver upon them is composed of a number of fine grains beautifully massed and interlaced together. In this condition they absorb the light, and have a peculiar dead white appearance, named matt in the plating trade. If the solution is contaminated with copper or other base metal, or if the current is too dense, or if the solution is deficient in silver, or if the voltage of the current is too high, the deposit will have a hard and dark appearance, and will be intractable to the burnisher. If the current is too large, the silver will go on loosely in dark gray grains, and the deposit is said to be burnt. This may be prevented by interposing a resistance in the circuit, and thus checking the volume of current passing through the article being plated. It may also be prevented by moving the article at a greater distance from the anode, or by placing more articles in the vat, or by lessening the anode surface exposed to the solution. If the voltage of the current is too high, the bad effects will be intensified, providing the volume of the current is also large, but a thin current with a high voltage will also deposit silver in a hard, dark condition, different from that above noticed. For this there is no other remedy except that of reducing the voltage by running the dynamo at a slower speed, or taking off some of the battery cells and reducing the number in series. If the hard, dark appearance of the deposit is due to a deficiency of silver in the solution, it must be remedied by adding more silver cyanide, or working with a weaker current and placing the articles nearer the anode. If the solution is contaminated with copper or other base metal, it is only fit for the most common work, and can only be remedied by turning it over to the refiner to be evaporated and reduced to old silver. One other cause of hard, dark silver is due to the addition of brightening liquid to the solution, to get a bright deposit from it. A solution thus treated is spoiled for general work and will rarely recover its former condition.

If silver-plated articles are exposed for a few minutes to the air and light after taking them from the bath, before rinsing them, the deposit will turn yellow. This is due to the action of light and air on the sub-cyanide of silver left on the surface. To prevent this, gently swill the articles to and fro for a few moments in the plating solution after disconnecting them from the cathode, rinse them at once in hot water and place them in hot, clean box wood sawdust. Extra care should be taken in this finishing operation when the surface has to be left dead white instead of being polished or burnished.

Thickness of Silver Deposits. It is not practicable to gauge the thickness of a silver deposit with a pair of calipers, or even with a micrometer caliper gauge, but the thickness may be ascertained if its superficial area and weight are known. The first can be obtained by exact measurement and calculation, and the next by noting the difference between the weight of the article both before and after plating. The weight of silver may also be approximately known by noting the volume of current passing through the solution in a given time. Thus it takes one

TABLE SHOWING THE RATE OF SILVER DEPOSITS.

Square Feet Exposed.	Rate of Current in Amperes.	Grains of Silver Deposited in One Hour.	Grains of Silver Deposited in One Day of Ten Hours.
.10	1	61.344	613.44
.20	2	122.688	1226.88
.30	3	184.032	1840.32
.40	4	245.376	2453.76
.50	5	306.720	3067.20
.60	6	368.064	3680.64
.70	7	429.408	4294.08
.80	8	490.752	4907.52
.90	9	552.096	5520.96
1.00	10	613.440	6134.40
2.00	20	1226.880	12268.80
3.00	30	1840.320	18403.20
4.00	40	2453.760	24537.60
5.00	50	3067.200	30672.00
6.00	60	3680.640	36806.40
7.00	70	4294.080	42940.80
8.00	80	4907.520	49075.20
9.00	90	5520.960	55209.60
10.00	100	6134.400	61344.00

ampere of current per second to deposit .017064 grains of silver. If this volume of current passes through the solution for one hour, it should deposit 61.344 grains of silver, and this should be the weight of silver acquired by the article. If the coated surface be measured, the thickness of the silver coat may be accurately obtained. The following calculations may help the plater to determine the thickness of the silver deposit.

Upon referring to the table the plater can ascertain at a glance how much current will be required to coat a surface with silver, or how much surface a certain volume of current will coat properly, or how much silver will be deposited by a known volume of current in a given time. It should be clearly understood, however, that the above figures relate solely to the actual volume of current passing through a solution as measured by an ammeter in circuit, but not to the mere capacity of the generator as ascertained by measurement of the current on short circuit between its poles. When dynamos are advertised as having a capacity of so many amperes or so many ounces of silver per hour, the figures merely give an idea of their maximum output, without reference to the resistance of the circuit. The maximum current obtainable from a dynamo can only be made available in depositing silver when the resistance of the conducting wire is low, and the full surfaces of anode and cathode are exposed to the plating solution.

Bright Silver-plating. Silver is deposited from a silver-plating solution in a matt condition without luster, and is afterwards made bright by scratch-brushing, polishing and burnishing. It is sometimes desirable to deposit silver in a bright condition upon parts that will not admit of being burnished. This is effected by adding a solution of carbon bisulphide to the plating solution and stirring it in well some hours before the operation of plating. The following is a most convenient method for preparing a brightening solution. Procure one quart of old silver solution, place it in a bottle capable of holding two quarts and furnished with a glass stopper. Add to this two fluid ounces of carbon bisulphide, place the stopper in the bottle and shake well together, then nearly fill the bottle with a strong solution of potassium cyanide, again shake well together, and then set aside in a cool place for twenty-four hours. The solution for bright plating should either be an old one, or one set aside for the purpose. To this add two fluid ounces of the brightening solution as often as may be required. Too much of this will spoil the plating solution, and the deposit of silver will be brownish or spotted with brown spots. The bright deposit spreads from the lower parts of the articles upward until all has been covered. It is darker than ordinary silver, and the somber hue deepens after the article has been removed from the solution unless well rinsed in boiling water. Bisulphide of carbon has a noxious odor and its vapor is inflammable and highly poisonous. It should therefore be used with caution and kept in a closely stoppered bottle in a cool place. Its solution with cyanide of potassium gradually turns black, but the blackness may be lessened by adding plenty of free cyanide.

Nitrate of Silver. This is the salt of silver used in making up silver-plating solutions. Other salts, such as the chloride, sulphide, oxide, sulphite, hyposulphite, acetate, iodide, and chromate of silver, may be mentioned, but most of them are made from the nitrate of silver, and all except this one are unsuitable for conversion into cyanide of silver on account of the bad effects of the by-products formed in the process of conversion. In using nitrate of silver there is no waste, since the salt is perfectly soluble in distilled water, from which all the silver can be precipitated as a single cyanide of silver. The nitrate can be cheaply and easily made, and can also be purchased at a reasonably low price in a state of purity.

It must be understood that only perfectly pure silver is admissible in a silver-plating solution. Standard silver is useless, because this contains copper, as does also nearly all commercial silver, but alloyed silver may be refined by the plater and then converted into the pure silver nitrate. But, if pure nitrate of silver is desired, pure silver in the form of silver foil or grain silver must be had. This obtained, dissolve the pure metal in a warm mixture of 4 parts of pure nitric acid and 1 part of distilled water and evaporate off all excess of acid to form the desired silver salt. As this may still contain some free acid, it is advisable to dissolve the salt in distilled water and again evaporate and re-crystallize the silver nitrate. If now the salt contains any copper, it will be shown on the sides of the evaporating dish in greenish or slightly blue streaks and spots. To demonstrate the presence of copper, dissolve a small portion of the nitrate of silver in a test tube with a little distilled water and add to it a few drops of diluted liquor ammonia. If copper is present in the nitrate solution, a blue ring will be formed in the test tube where the ammonia meets the nitrate of copper, and the intensity of this blue ring will show at once whether the copper is present in a large or in a small quantity. If copper is detected, the whole mass of silver nitrate must be dissolved in distilled water, and common salt (sodium chloride) added as long as a white precipitate of silver chloride is thrown down. The liquid above this will contain all the copper in the form of copper chloride, and as this is soluble in water, while the silver chloride is not, the two may be entirely separated by pouring away the supernatant liquor and washing the silver chloride several times in an abundance of clean hot water. This is done by pouring distilled water into the vessel containing the silver chloride, stirring it up well with a glass rod, allowing the white powder to subside and then pouring off the water. It is not necessary to pour off the last few drops of water each time, and at the last some of it may be left to cover the precipitate, and to this should be added a small quantity of hydrochloric acid. Some clean scraps of zinc or some granulated zinc must now be well stirred into the silver chloride precipitate and frequently moved about in it. The chlorine in the silver chloride, having a stronger affinity for zinc than it has for silver, will now leave the silver in the form of very small gray grains and combine with the zinc to form soluble zinc chloride. When all the silver chloride has been thus decomposed, and not a trace of the white precipitate remains, stir in a little more hydrochloric acid and pour off the zinc chloride solution. Next add equal parts of hydrochloric acid and water to the gray mass remaining, and stir up well for several minutes to completely dissolve the last trace of zinc remaining entangled in the silver grains and finally well wash the mass in an abundance of water, using distilled water for the last two washings. The gray, wet mass should now be perfectly pure silver, which may be dried and melted in a crucible under a layer of charcoal, or dissolved at once in dilute nitric acid to form silver nitrate.

This operation must be performed in a cupboard, or in a fireplace with a very good draught to carry away the highly poisonous fumes of nitrous oxide thrown off from the solution. It is best carried on in a porcelain beaker or an evaporating dish over a sand bath heated by a small gas stove. Only enough acid should be employed to dissolve all the silver, as all excess acid will be wasted. The right quantity is about four fluid ounces of acid and one of distilled water to each ounce of silver. The heat applied should be very moderate at first, until all the silver has been dissolved, then increased to evaporate the excess of water and acid, but in no case should the solution be allowed to boil. When it has become thick it may be taken off the stove and set aside to cool. As the thick liquor cools it will congeal to a mass of crystals, and these may hold some free acid. This may be removed by dissolving the crystals in distilled water and evaporating the solution again. All free acid left in a silver nitrate solution means a corresponding loss of silver and of cyanide when making up the cyanide of silver solution, as the acid decomposes part of the cyanide of potassium, converting it into nitrate of potash and free cyanide gas, while some of the silver is left in the solution.

Cyanide of Silver. The single cyanide of silver is prepared from nitrate of silver by adding a solution of cyanide of potassium to a solution of silver nitrate as long as a precipitate is formed. This precipitate is in the form of small white grains and is composed of one equivalent of silver, 108 parts, added to one equivalent of cyanogen, 26 parts, making cyanide of silver having a molecular weight of 134. The action which takes places on adding the two solutions is as follows: Potassium cyanide added to silver nitrate exchanges its cyanogen for the nitrogen and oxygen of the silver nitrate and becomes nitrate of potash, whilst the cyanogen unites with an equivalent of silver to form silver cyanide. As nitrate of potash is soluble in water and cyanide of silver is not soluble in water, it is only necessary to pour off the supernatant liquor and wash the precipitate in water to obtain pure cyanide of silver.

The most practical method of making silver cyanide for electro-plating purposes is as follows: Dissolve the silver nitrate in distilled water or in clean rain water in the proportion of 1½ ounces troy of the salt in half a gallon of water. Next make a solution of cyanide of potassium in distilled water or in clean rain water in the proportion of one ounce troy of 90 per cent cyanide to one quart of water. Add this gradually, with frequent stirring, to the silver nitrate solution, pouring in the last few drams carefully and noting the result. If the precipitate settles down and leaves the supernatant liquid clear, enough cyanide has been added, but if the liquid is cloudy, make up some more cyanide solution and add this drop by drop until the cloudy appearance has been removed. If too much cyanide is added it will dissolve some of the precipitate and give a slightly brown tint to the supernatant liquid as it passes through. In this case add a few drops of silver nitrate solution until it ceases to form a white, cloudy precipitate. This operation is best carried on in a glass vessel, such as a bell glass fixed in a stand of wood, or in the glass cell of an accumulator. When all the precipitate has settled down, the supernatant liquor must be poured off into another vessel and treated for recovery of silver, and the silver cyanide well washed with water. It is then ready to be dissolved in a strong cyanide solution to form the plating bath, or may be dried gently on a water bath and be stored away in glass jars for future use. Cyanide of silver is insoluble in water and in cold nitric acid, but is freely soluble in solutions of ammonia, carbonate of ammonia, nitrate of ammonia, sal-ammoniac, hyposulphite of soda, the cyanides of ammonium, sodium, and potassium, ferro-cyanide of potassium, and in solutions of the alkaline chlorides. Hydrochloric acid decomposes it with an evolution of hydrocyanic acid gas. Boiling sulphuric acid and water has a similar effect, and produces a formation of silver sulphate. The gas given off in these reactions is dangerously poisonous and must not be inhaled, as its effects are identical with those of prussic acid. It must be also understood that all the cyanides are equally dangerous poisons and must be used with great care to avoid fatal consequences.

Double Cyanide of Silver and Potassium. This salt, dissolved in distilled water, forms the best solution for silver-plating purposes. It is formed by dissolving an equivalent of silver cyanide, 134 parts, in a solution containing an equivalent of pure cyanide of potassium, 65 parts, the resulting salt being composed of one equivalent of silver, 108 parts, one equivalent of potassium, 39 parts, and two equivalents of cyanogen, 52 parts, making together a double salt having the molecular weight 199.

In practice, the silver-plating solution of this salt is formed by dissolving the wet cyanide of silver, freshly prepared, in a solution containing as much cyanide of potassium as it takes to throw down the silver cyanide, and then adding about one-fifth more of potassium cyanide to form free cyanide, this excess being necessary to dissolve the silver anode and keep the solution in working order. This solution is then made up with distilled water so as to contain a certain weight of silver per gallon, which may vary from half an ounce up to 5 ounces or more to the gallon.

The variation in the strengths of silver-plating solutions adopted by platers is regulated by the special requirements of the trade in which each workman is employed. Attenuated solutions containing from one-quarter ounce to one ounce of silver in the gallon, deposit their silver more slowly than rich solutions containing from 4 ounces to 6 ounces of silver in the gallon, but the deposit from each and all may be equally good. As weak solutions are bad conductors of the current, a higher voltage must be employed to force the current through them than will be found necessary in richer solutions. The amount of silver per gallon may be determined at the outset by reckoning each 170 ounces of silver nitrate to yield 108 ounces of pure silver.

The quantity of excess cyanide of potassium in each gallon of solution also varies with the requirements of the work to be done in the solution. This should, however, be lessened if such metals as bare copper, coppered zinc, coppered iron, or any other metal or alloy on which cyanide of potassium acts quickly, or on which silver is readily deposited from its plating solution, is to be plated in the solution. It is just in such instances as these where quickening the surface with mercury comes in useful. It is possible to so arrange the proportion of free cyanide in a solution as to suit exactly one class of work and to deposit an adherent coat of silver in this class without quickening the surface, but it is not always convenient to do so.

ELECTRO-PLATING WITH GOLD

Gold is easily electro-deposited from all its solutions by a small current of electricity, but the deposits of gold are not all equally good from all solutions. Although it is a metal easily deposited, there is no other capable of such an infinite variety in the color and character of the deposit. This varies with the character of the solution from which it was deposited, the temperature of the solution at the time of deposition, and the current employed to deposit the metal. As gold is deposited from its solution in potassium cyanide in good condition and color, this solution has become the general favorite with electro-gilders.

Terchloride of Gold. As this soluble salt of gold can be readily prepared, it is used generally in making up gold solutions. It is easily made by dissolving pure gold in a solution of aqua regia, evaporating the excess of acid and continuing the heat until the salt forms ruby red crystals on the sides of the evaporating dish. The details of this process are as follow: Make up a mixture of 3 parts of pure hydrochloric acid, 1 part of pure nitric acid, and 1 part of distilled water, to dissolve 1 part of pure gold, that is to say, it will take 6 fluid ounces of this mixture to dissolve 1 Troy ounce of pure gold. The acid mixture must be placed in a large glass beaker or large porcelain evaporating dish, over a sand bath or water bath, in a cupboard or in some place where the highly poisonous and corrosive fumes of the mixture can be carried away by a strong draught. Heat must then be applied to the sand bath until the mixture becomes warm, when the gold must be added in small quantities at a time until all the gold is dissolved or the warm acid ceases to take up any more. During this operation dense brown fumes of a penetrating, pungent and strongly corrosive character will be given off from the mixture. The heat must be continued below boiling point, until all excess of acid and water has been driven off in the form of steam and only a dark, thick liquid remains at the bottom of the evaporating dish. The operator should protect his hands with a pair of thick gloves, and then proceed to turn the dish about, tilting it from side to side until the dark liquid all crystallizes on the sides of the dish in the form of ruby red crystals. The whole contents of the dish should then be dissolved in hot distilled water and set aside to cool, when it must be filtered through blotting paper to remove any dirt contracted in the previous process. If any brown powder remains at the bottom of the dish, it is in all probability finely divided gold, and this must be dissolved in a little more of the acid mixture and treated like the bulk of the sample. As gold is a very precious metal, great care must be exercised to avoid waste, and all rinsings of the vessels, together with washings of the filter, must be made with distilled water and then added to the filtered solution. The terchloride of gold solution thus made may be again evaporated over a water-bath at a low temperature, and the dried salt stored away in wide mouthed bottles, or the solution may be diluted with distilled water and treated direct with cyanide of potassium to form gold cyanide.

Terchloride of gold is formed of three equivalents of chlorine (35.5 × 3) added to one equivalent (197) of gold, and has, therefore, the molecular weight 302.15. It is very soluble in water and its solution stains the skin a dark purple tint.

Cyanide of Gold. Cyanide of gold is formed as a yellow precipitate when a solution of cyanide of potassium is added to a solution of terchloride of gold in distilled water. The precipitate forms slowly and falls tardily. In making cyanide of gold, the terchloride solution should be largely diluted with distilled water, so as to contain not more than one ounce of gold in half a gallon of water, and the solution of cyanide should also be very dilute to produce good results. If the terchloride solution is too dense, or contains any free acid, or the cyanide solution is too strong, a large proportion of the gold will enter into combination with the cyanide of potassium to form a double soluble salt of gold and potassium, and thus be taken up by the supernatant liquid. Even when the greatest care is exercised in making this salt, some gold is found in the supernatant liquid and in the wash waters. These should be carefully preserved and treated for the recovery of the gold. The details of the process for making cyanide of gold are precisely the same as those for making cyanide of silver, but, owing to the difficulties experienced in determining the end of the process, and the loss of metal likely to be sustained by the operation, it should only be undertaken by experienced persons.

Double Cyanide of Gold and Potassium. When an excess of cyanide of potassium solution is added to the yellow cyanide of gold precipitate, it dissolves and forms a solution containing the double cyanide of gold and potassium. If the gold cyanide has been properly prepared and washed, as directed for the silver cyanide, this solution is undoubtedly the best for electro-gilding.

The double cyanide of gold is composed of one equivalent of gold and one equivalent of potassium added to two equivalents of cyanogen. But the gilding solutions made by inexperienced operators usually contain a large addition of chloride of potash, formed whilst attempting to throw down the gold cyanide.

Owing to the difficulty experienced by many operators in precipitating the cyanide of gold, many makeshifts have been resorted to with a view to avoid having chloride of potash in solution. If an excess of liquid ammonia is added to a solution of terchloride of gold, a brown precipitate is formed. This is an oxide of gold, having dangerously fulminating properties when dried, as it will then explode violently if heated or subjected to friction. This precipitate must therefore be well washed and dissolved whilst wet in a solution of potassium cyanide to form the gilding bath. It must then be boiled for several minutes to expel the ammonia still held in the solution. This is a fairly good solution, yielding a rich gold deposit when first made up, but liable to deposit a darker gold as it gets older. As it is made from oxide of gold dissolved in cyanide of potassium, it contains an oxide of potash in addition to the double salt of gold and potassium. The same is true of all solutions made from oxide of gold, which may be prepared in another way by adding calcined magnesia to the terchloride of gold solution as long as a brown precipitate falls. This must be removed from the solution by filtration, and then digested in dilute nitric acid to remove the excess magnesia. The gold oxide must then be well washed to remove the last trace of acid, and dissolved in a solution of cyanide of potassium to form the gilding bath in the usual manner.

Another solution may be made by first throwing down all the gold as a precipitate from its terchloride solution by adding sulphide of ammonium. This precipitate is to be well washed and dissolved while wet in a solution of cyanide of potassium to form the gilding bath. It must then be boiled for half an hour to expel the excess ammonia, and the loss due to evaporation made up with distilled water. With a moderate excess of free cyanide, this solution will yield a fine color when worked at a temperature of 130 degrees Fahrenheit, and will give good results for a considerable period.

Characteristics of Gold Deposits. When gold is deposited from a cold or cool solution it has a paler tint and is less coherent than when deposited from a hot solution. A rise in temperature causes the gold to be deposited faster and assume a brown tint, which disappears on scratch-brushing the article. Movement of the article being gilded has a tendency to prevent this dark brown appearance and cause a lighter colored deposit. If a thick deposit is desired, the article should be taken from the bath every few minutes, scratch-brushed to remove the brown appearance, and returned to the bath for another coat.

Gilding Bath, Strength of. Gilding baths will yield good results with only 5 pennyweights of gold in each gallon of solution, if worked under suitable conditions, or they will yield equally good deposits with one ounce or more of gold in each gallon of solution. A very good working strength is insured with from 10 to 15 pennyweights of gold to the gallon. Solutions poor in gold are liable to great fluctuations in the color of the deposit, which will assume a dark, hard appearance, resembling 15-carat gold, if the battery voltage is too high. A similar appearance will result from the presence of too much free cyanide. A great excess of free cyanide will cause the gold deposit to assume a foxy-red tint, which cannot be altered by subsequent scratch-brushing and polishing. Solutions too rich in gold, deposit the metal too fast, and in a non-coherent condition liable to strip under the burnisher. This condition is intensified if the solution contains an excess of free cyanide in addition to an excess of gold.

Polishing and Finishing Electro-gilt Articles. After the articles have received the desired coat of gold, they should be rinsed in clean warm water and scratch-brushed whilst wet, then polished and finished. If it is necessary to burnish parts of the work, full directions for this process will be found.

Assaying Gold and Silver Solutions. The exact strength of a gold or silver solution may be ascertained in the following manner: Take one fluid ounce of the solution and evaporate it to dryness in a porcelain dish, in a sand bath over a small gas stove. To the dried salt add an equal bulk of litharge and mix the whole well together. Calcine the mixture in a small crucible and keep it at a glowing red heat until all the litharge has been decomposed and a small pool of molten lead appears at the bottom of the crucible. This lead will contain all the silver or gold in the sample to be assayed, and must be poured out on a clean iron slab to cool. The button of lead must now be placed on a boneash cupel (a small cup of boneash) and subjected to a strong heat in the presence of air until all the lead has been oxidized and absorbed into the boneash of the cupel and only a button of pure gold or pure silver remains. This must be allowed to cool on the cupel, from which it can be easily detached, then cleaned from adhering boneash and exactly weighed. The weight of the button thus obtained should be of $\frac{1}{160}$ that of the silver or gold in a gallon of the solution, therefore if the weight is multiplied by 160 (the number of fluid ounces in a gallon), the exact weight of precious metal in a gallon will be obtained.

ELECTRO-PLATING WITH COPPER

Copper is deposited from an acid solution of copper sulphate in the various processes of electrotyping and copying artistic objects in this metal. The deposits thus obtained are removable from the moulds on which they are deposited, and afterwards have a separate existence of their own. The process of obtaining them, therefore, cannot be deemed a branch of electro-plating proper, but forms a separate art. Copper is employed chiefly as a coating on such metals as iron, steel, zinc, tin, lead, pewter, and white metal when preparing these to receive a deposit of silver, because silver will not adhere perfectly to iron, steel, zinc, tin, or lead when deposited upon these metals direct, but will adhere perfectly to copper when deposited on these metals, and copper can be made to adhere firmly to each and all of them. A coat of copper is also preferred by some platers on such alloys of tin and lead as pewter and white metal before these are plated with silver, because a firm and adherent deposit of silver can only be obtained on these alloys by spcial precautions taken in their preparation. It is also deposited on articles made of iron and of zinc, and the coating is subsequently subjected to the action of acids to produce bronzing effects on the copper coating. It is likewise employed as a preparatory coating to a deposit of gold and of nickel on the above-named metals, although this is not always necessary, since gold and nickel can be firmly deposited on iron, steel, zinc, etc., without the intervention of copper.

Alkaline Solutions of Copper. As all acid solutions of copper, even the saturated solution of copper sulphate, deposit their metal on iron, steel, zinc, lead, and its alloys by simple immersion or chemical displacement, they are unsuitable as depositing solutions for electroplating with copper, since such deposits are never firmly adherent to the metal on which they are deposited. We have therefore to employ an alkaline solution which will not deposit its metal by simple immersion on those we wish to cover. Several various solutions have been employed, among which may be mentioned a solution of cyanide of copper and bisulphite of sodium, a solution of bitartrate of potash and carbonate of copper, a solution of cyanide of copper and tartrate of ammonia, a solution of phosphate of copper and ammonia, and also a solution of sulphate of copper, tartrate of potash and caustic soda.

Cyanide of Copper Solution. The solution in general use for coppering iron and zinc is that of the double cyanide of copper and potassium. This may be readily prepared by the battery process, as directed for preparing gold solutions, using an anode of pure copper in a hot solution of cyanide of potassium. Or it may be prepared by throwing down the copper from any of its acid solutions, as cyanide of copper, and then dissolving this in a solution of potassium cyanide, by the process given for making up the solution of double cyanide of silver and potassium. This solution possesses the disadvantage of having to be used at a temperature of from 160 to 180 degrees Fahrenheit, and it does not freely dissolve the anode unless a large excess of free cyanide is present in the solution, and this excess is detrimental to the deposit of copper, since it has a tendency to dissolve the newly deposited coat and make it loose or spongy.

Alkaline Copper Solution. The best alkaline copper solution is made as follows: Dissolve eight ounces of copper sulphate in one quart of hot rain or distilled water and set aside to cool. When cool, add liquid ammonia, whilst stirring with a stick or glass rod. At first a green precipitate will fall, and then this will dissolve on adding more ammonia, until the whole solution assumes a blue tint. Dilute this with an equal bulk of cold rain water and add to it enough solution of potassium cyanide, whilst stirring, to destroy the blue color of the ammonia sulphate and give the color of old ale to the solution. Set this aside for a few hours, then pass it through a linen filter and make it up to a gallon of solution with rain or distilled water. This solution may be worked cold, but the rate of deposition is increased and the deposited copper of improved quality when the solution is heated to a temperature of from 110 to 130 degrees Fahrenheit.

Working Alkaline Copper Solutions. As the affinity between copper and cyanide is stronger than that between copper and acid, it takes a higher voltage to separate them and deposit the copper in good condition. Copper may be deposited from an acid solution with a voltage of less than 1 volt, but it takes a voltage of from 6 to 8 volts to deposit copper on iron from an alkaline solution. Gas must be freely given off from the article whilst deposition is proceeding, but the volume of gas must be reduced by reducing the voltage of the current if the deposit shows a tendency to become dark and sandy. An anode of pure copper must always be employed. If the anode coats itself with a green crust soon after deposition commences, add some liquid ammonia, whilst stirring the solution, until the green crust dissolves and the anode works clean. If the anode becomes coated with a blue crust, add cyanide of potassium solution. By thus noting the condition of the anode and adding ammonia or cyanide as required from time to time, the solution may be kept in working order. It is not usual to deposit thick coats of copper from alkaline copper solutions, but to just cover the article with copper and then transfer it at once to the plating solution before the pure copper coat can become oxidized by the action of the air. When thick deposits of copper are required, the articles are transferred from the copper plating bath at once to an acid solution of copper sulphate, and deposition continued in this until the desired thickness of copper has been obtained.

Rate and Thickness of Copper Deposits. Copper is deposited from its solutions in good condition at the rate of .05045354 grains per second with 1 ampere of current, or at the rate of 18.163 grains per ampere-hour. With 1 ampere of current depositing copper on one-tenth of a square foot of surface, 181.63 grains are deposited in 10 hours, while with 10 amperes of current 181.63 grains of copper are deposited on 1 square foot of surface in 1 hour, and with 100 amperes 1816.3 grains of copper are deposited per hour. The rate of deposit suitable for a known surface can thus be readily ascertained, together with the volume of current necessary to effect the desired deposit in a given time, bearing in mind always that to force copper rapidly on a small surface it will be necessary to increase the voltage of the current, and this may deposit brittle metal. The thickness of a copper deposit may be ascertained by calculating each 2.2468 grains per square inch to measure one-thousandth of an inch in thickness.

ELECTRO-PLATING WITH ZINC, TIN, IRON AND PLATINUM

Electro-plating with Zinc. Zinc has been electro-deposited from a solution of its sulphate by the use of a feeble current. It has also been deposited from its solutions of chloride, acetate, tartrate, ammonia sulphate, and ammonia chloride.

Zinc-plating Solution. Dissolve 200 ounces of best cyanide of potassium in 20 gallons of water and stir into this 80 ounces of strong liquid ammonia. Place several large, clean, porous cells in the solution, and fill these with the bath liquid. In each cell suspend a strip of copper, and connect each strip to the negative pole of a strong battery or a plating dynamo. From the other pole suspend a large anode of zinc and pass a current until 60 ounces of zinc have been dissolved from the anode. Next dissolve 80 ounces of carbonate of potash in part of the bath solution, stir this into the main bulk and let it rest for 12 hours. Filter the bath before using and work it with a current of from 4 to 5 volts, using anodes of milled zinc. The articles to be zinc-plated should be cleaned and treated as for silver-plating, but not quickened in mercury.

Tin-plating. The so-called tin vessels commonly in use for domestic and other purposes are made of thin sheet iron coated with tin. The sheets of iron are dipped in a bath of molten tin, and thus acquire a thin film of this metal. The insides of copper and iron vessels employed for culinary purposes are coated with tin by a similar process. Whenever it is deemed desirable to coat an article with tin, it may be cheaply and expeditiously done by this, the molten process. Small brass articles, such as pins, hooks and eyes, and small copper articles, such as hooks and buttons, may be easily coated with tin by simple immersion in a bath composed of a saturated solution of cream of tartar in which has been dissolved a small quantity of chloride of tin. The quantity of this salt is immaterial, as it is only employed to start the process, the remaining tin being supplied from anodes of sheet tin suspended in the bath. The liquid is kept at a boiling temperature and the articles to be tinned are suspended in the bath between the tin anodes until sufficiently whitened, when they are rinsed in water and rattled about in hot bran until dry and bright. Iron articles may be similarly whitened in a boiling solution made by dissolving 3 drams of fused protochloride of tin and 6 ounces of ammonia alum in one and a quarter gallons of water. Bronze may be coated with tin in a hot solution of caustic soda in contact with anodes of pure tin.

Electro-plating with Tin. Tin may be readily deposited by the single cell process from its solution in caustic soda or in caustic potash. Make up a strong solution of either of those caustic alkalies, and add to it a small quantity of perchloride of tin, also put some plates of pure tin in the cell. Place some of the caustic alkali solution in porous cells with strips or bars of zinc, and connect the articles to be tinned to copper wires attached to the zinc and immerse the whole in the tinning solution. Solutions for the electrodeposition of tin with current from a separate battery are here given. Solution No. 1 is made in the following manner: Dissolve 30 pounds of caustic potash in 20 gallons of water, 30 pounds of cyanide of potassium in 20 gallons of water, and 30 pounds of pyrophosphate of soda in 60 gallons of water. Into the caustic potash solution pour gently, whilst stirring all the time with a glass rod, 200 fluid ounces of the chloride of tin solution, then all the cyanide solution, and lastly all the soda solution. This solution is used for tinning zinc articles and is worked at a temperature of 70 degrees Fahrenheit, with a current having an electromotive force of from 3 to 4 volts. Solution No. 2 is made up of 20 pounds pyrophosphate of soda dissolved in 40 gallons of water into which is poured 100 fluid ounces of the chloride of tin solution, and, finally, there is added to this 56 pounds of sal-ammoniac dissolved in 60 gallons of water. This solution may be worked with a weaker current than that employed for No 1 solution, but must be used at a temperature of from 100 to 110 degrees Fahrenheit,

Electro-plating with Iron. Iron may be deposited from suitable solutions, in a condition resembling hard steel, and in this state has been found useful for facing printers' type, engraved copper plates, and electrotypes of copper. The process has been named acierage, or steel-facing. Various solutions have been tried for the purpose. One solution is made as follows: Dissolve a quantity of iron sulphate in water and add a solution of ammonia carbonate until all the iron has been thrown down. Wash the precipitate several times, and dissolve it in sulphuric acid, taking care to only add as much acid as will dissolve the precipitate. Use this solution in a concentrated state, with iron anodes having a combined surface some seven or eight times larger than the copper surface to be coated. The bath must not be allowed to get acid, so it must be kept well supplied with iron, and it is advisable to add carbonate of ammonia occasionally. The copper plate to be steel-faced must be well cleaned with benzine, then with caustic potash, and well rinsed in water. It should be placed at once in the iron solution and well scrubbed every five minutes, until a sufficient thickness of iron has been secured. When the face is deemed thick enough, wash it thoroughly in warm water, dry it quickly whilst rubbing with a soft brush, then coat it with a thin film of wax to preserve it from rust.

Good results have been obtained from a solution of the double salt of ammonio-sulphate of iron. Also from a solution of sulphate of iron and sulphate of ammonia, one part of iron sulphate to five parts of water. A solution of iron sulphate gives good results when sal-ammoniac is added to the bath. It is advisable to cover the surface of the bath with glycerine while at work, and to keep it under cover when not in use, to prevent decomposition by action of the air.

Electro-plating with Platinum. The peculiar character of platinum, as shown in its non-liability to corrosion in acid fumes and in all the simple acids, points to its usefulness as a protective coating to articles of brass, copper, German silver, etc., used in chemists' laboratories. With reasonable care in conducting the process, platinum can be deposited in good condition from a solution of the double cyanide of platinum and potassium in distilled water. The solution is to be made up as directed for making the double cyanide of gold and potassium, by precipitation from a dilute solution of chloride of platinum (made as directed for obtaining terchloride of gold), and dissolving the precipitate in a solution of cyanide of potassium. As platinum solutions are easily decomposed by the introduction of other metals, and thus always liable to deposit the metal by simple immersion, success is achieved in its electro-deposition only by employing dilute solutions and a low voltage. If a high voltage is used the deposit will be loose and spongy, presenting the appearance of black grains, instead of a reguline deposit.

The solution of double cyanide of platinum and potassium must therefore be very dilute, and care must be taken to add some chloride of platinum at frequent intervals to neutralize the free cyanide, and also to replenish the solution with metal, since platinum anodes are not soluble in solutions of potassium cyanide.

The following solution gives less trouble than that previously mentioned, but requires more battery power. Take 5 fluid ounces of platinic chloride containing one-quarter ounce of platinum in 5 ounces of water, and stir it into 10 pints of distilled water. Take 20 drams of crystallized phosphate of ammonia and dissolve it in distilled water, then add the solution to the platinic chloride solution whilst stirring it with a glass rod. Take 100 drams of crystallized phosphate of soda, dissolve in distilled water and stir this into the mixed solution before prepared, to dissolve the precipitate caused by adding the phosphate of ammonia. Boil the whole in an enameled iron vessel until it ceases to give out the odor of ammonia and will slightly redden blue litmus paper, it is then ready for use. Work the solution at a temperature of from 190 to 200 degrees Fahrenheit, using a large platinum anode and a current having a voltage of from 5 to 6 volts. As the anode does not dissolve in the solution, it is necessary to add some chloride of platinum occasionally to maintain the bath at its proper metal strength. This is best done at the close of an operation, adding just as much chloride as wil contain enough platinum to represent that drawn from the bath, and stirring all well together. It is also advisable to add occasionally a small quantity of phosphate of soda to dissolve any platinum precipitate which may form at the bottom of the bath and to prevent it from becoming too acid. This solution will deposit reguline platinum of the usual steel-gray appearance on copper and brass and alloys of copper. If it is wished to coat with platinum such metals as iron, zinc, lead, tin, or alloys of these metals, they must first be electro-coppered, since they decompose the platinum bath and deposit the metal on themselves by simple immersion.

ELECTRO-PLATING WITH ALLOYS

Alloyed metals may be successfully deposited by using two or more of the metals together which compose the alloy to be imitated. Thus, various proportions of copper and zinc may be deposited together to form varieties of brass and of bronze, or copper and tin may be deposited together to form bronze. Copper, zinc and nickel may be deposited together to form German silver. Some interesting effects may be produced by depositing gold and copper, gold and silver, gold, silver and copper, and copper and silver together, from mixtures of the double cyanide solutions of these metals. Greater skill and care must be exercised to successfully deposit an alloy than would be employed in depositing either of the metals composing the alloy. Special conditions must be adhered to respecting the regulation of the current strength, strength and condition of the bath, and surface of the anode employed. Any variation from these conditions will result in a variation in the composition and appearance of the deposited alloy. The color of alloys, made by melting two or more metals together, depends very largely on the proportionate parts of the composition. If equal bulks of copper and of zinc solutions containing equal weights of the two metals are mixed together a mixed deposit consisting of equal parts of the two metals copper and zinc will result. In practice, from such a solution a great variety in shades of brass may be obtained, depending on the temperature of the solution and the strength of the current. As the quantity of metal deposited from a solution depends greatly on its electric valency, and this varies with each metal, it becomes a matter of difficulty to always adjust the current to the composition of the solution so as to deposit each metal in the proportion desired to obtain a given effect of color in the deposited alloy.

Electro-deposition of Brass. Brass has been deposited from a great variety of brass solutions, as will be seen by reference to the annexed table. Among the first attempts to deposit brass may be mentioned that of M. de Ruolz in 1841, who employed a mixed solution of the double cyanides of copper, zinc and potassium. Cyanide of potassium forms an important ingredient in the majority of alloy solutions, but ammonia in some form is also necessary to keep the solutions in working order.

The following conditions are to be observed in making up the solutions according to the proportions given in the accompanying table. Fluid ounces are given for liquids and avoirdupois ounces for the solids. When potassium carbonate, carbonate of potash, is to be used, the copper and zinc salts are first dissolved in water and then precipitated as carbonates from this solution by adding a portion of the potassium

Alloy Plating Solutions.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Water	1280	5000	3200	5000	5000	800	160	160	250	1000
Copper Acetate	5					160				
" Chloride		10	16	25	15					
" Sulphate									1	25
" Cyanide							2	2		
Zinc Acetate						16				
" Cyanide							1	1		
" Sulphate	10	20	32	48	35				8	30
Potassium Acetate						160				
" Carbonate		160	400	610	500					
" Cyanide	8	24		12	50	q. s.	15	16	18	q. s.
" Caustic	72									
Ammonia Liquid	50	q. s.								
" Carbonate								16		
" Nitrate			200	305						
Soda Carbonate										200
" Bisulphite										50
Arsenious Acid										

carbonate. Where the sign q. s. is given in the table, a sufficient quantity of the ammonia or cyanide must be added to produce the desired effect, ammonia being generally employed to dissolve the precipitates, forming a deep blue liquid, and cyanide being used until the blue color has all disappeared. Both are employed as solvents to the anodes, which will not freely dissolve unless one or both are present in the solution. Even when an alloy solution is made up without the use of cyanide and ammonia, it is necessary to add them afterwards to keep the solutions in working order, as the ammonia alone does not freely dissolve the copper of the anode, and cyanide alone does not dissolve the zinc oxide formed on the anode. The following instructions apply to each numbered solution in the foregoing table.

1. Dissolve all the salts separately in portions of the water, add the ammonia in equal parts to the solutions of the copper and zinc salts with stirring, mix the copper and zinc solutions together, then add the caustic potash solution and lastly the cyanide solution, stir well at frequent intervals during the next twelve hours, then allow the solution to rest a short time before working it. 2. Dissolve all the salts separately, pour enough potash solution into the solutions of copper and zinc to precipitate all the metal, add ammonia until the precipitate has been dissolved, decolorize with the cyanide, then add remainder of potash and water. 3. Dissolve all separately, mix

copper, zinc and potash solutions, then add the nitrate of ammonia. 4. Proceed in a similar manner as for No. 3 solution. 5. Proceed in a similar manner as for No. 3 solution. 6. Dissolve all the salts, add the cyanide solution to the others while stirring. 7. Dissolve all the salts in distilled water, mix together and add two ounces of sal-ammoniac. 8. Dissolve all the salts separately, then mix together. 9. Dissolve the copper and zinc salts and mix the solutions, add a solution of 100 parts of the carbonate of soda and stir well together, when the precipitate has subsided pour off the clear liquor, wash the precipitate, add the remainder of the carbonate of soda together with the bisulphite of soda previously dissolved in water, then add enough cyanide to dissolve the precipitate.

Brass Solution. Dissolve sheet brass in nitric acid and use this solution instead of copper and zinc salts in making up the brass bath. To do this properly dissolve the strips of sheet brass in warm dilute nitric acid until the acid ceases to dissolve any more brass. Avoid the poisonous fumes as in dissolving silver, add the brass solution to water in the proportion of one ounce of brass to half a gallon of water, to this add strong liquid ammonia until the solution assumes a clear deep blue color, to this add a strong solution of potassium cyanide until the blue color entirely disappears and the solution assumes the tint of old ale, then filter and make up with water so as to contain one ounce of brass in the gallon of solution. This solution will work well cold or hot, but should be left at rest for some hours after being made before it is used.

Management of Brass Solutions. Brass solutions are not easily managed, but require constant attention to keep them in proper working order. The anodes may be of good sheet brass, or they may be of best rolled sheet zinc and sheets of copper in equal numbers. Unless the anodes work clean, that is, dissolve freely, the solution will become poor in metal and deposit an undesirable variety of brass. The zinc of the anodes is apt to be especially troublesome because the oxide of zinc formed upon them does not freely dissolve in the solution. To remedy this defect employ an excess of liquid ammonia in solution. If there is an excess of zinc in the solution add more free cyanide, and this will dissolve the copper part of the anodes. To get a solution into working order after it has fallen into a bad condition, add carbonate of copper or carbonate of zinc dissolved in liquid ammonia, as may be required. If the deposit lacks brightness, dissolve a few grains of white arsenic in a hot solution of cyanide of potassium, and add this to the bath with stirring. An excess of this will give the deposit a steely gray appearance. The deposit of brass will vary with the strength of the current. A current of high voltage tends to deposit an excess of zinc, while one of too low voltage may deposit an excess of copper. The deposit, however, will be greatly affected by the volume of current passing, and this may be controlled by the resistance of the conductors in circuit. Thus with large conductors and anodes close to the article being plated an excess of zinc may be had, while with smaller conductors, good brass or an excess of copper. The density or the temperature of the solution will also affect the deposit, dense solutions at high temperatures being better conductors than dilute solutions at low temperatures. These remarks apply to all brassing solutions, which will generally yield results according to the skill and experience of the operator.

Voltage Required for Brass-plating. Brass-plating solutions require a voltage of from 6 to 9 volts, according to their composition, to deposit a good coat of brass. The current must be regulated according to the kind of brass desired.

Bronzing Brass by Immersion. Brass may be bronzed in various colors by simple immersion in the solutions given in the accompanying table.

In the preparation of No. 5, the liquid must be brought to a boil and then allowed to cool. In using No. 13, the heat of the liquid must not be under 180 degrees Fahrenheit. No. 6 is slow in action. The action of the others is for the most part immediate.

Cyanide of Potassium. All directions involving the use of cyanide of potassium in given weights and proportions must be qualified by the known quality of the cyanide about to be used. No other material used by the plater is so liable to variations in quality. The quality is determin-

BRONZING BRASS BY IMMERSION IN THE FOLLOWING SOLUTIONS.

	Water.	Nitrate of Iron.	Perchloride of Iron.	Permuriate of Iron.	Nitrate of Copper.	Tersulphide of Arsenic.	Muriate of Arsenic.	Potash Solution of Sulphur.	Pearl-ash Solution.	Cyanide of Potassium.	Ferro-cyanide of Potassium.	Sulpho-cyanide of Potassium.	Hypo-sulphide of Soda.	Nitric Acid.	Oxalic Acid.	Color.
No.	pt.	dr.	dr.	pt.	oz.	gr.	oz.	dr.	dr.	oz.	pt.	dr.	dr.	dr.	oz.	
1	1	5														Brown and every shade to black.
2	1		5													Brown and every shade to black.
3	1	16											16			Brown and every shade to red.
4	1												16	1		Brown and every shade to red.
5	1				1										1	Brownish red.
6											1			3		Brownish red.
7	1									1				4		Dark brown.
8	1					30			6							Yellow to red.
9	1							1								Orange.
10	2			1												Olive-green.
11	1		5									2				Slate.
12	1												20			Blue.
13	1						1									Steel-gray.
14	1			2			10									Black.

able by the amount of cyanogen contained in the salt. Each 65 parts should contain 26 parts of cyanogen and 39 parts of potassium, but the best commercial cyanide rarely assays 98 per cent of cyanide of potassium, indeed it is a good sample which will show 95 per cent of pure cyanide. The impurities may consist of iron, carbon, silica, and the carbonate, sulphide, chloride, cyanate and ferrocyanide of potassium. Some of these are contracted during the process of manufacture. Carbon is added to the salt whilst in process of manufacture, to prevent formation of the cyanate, and this gives to some samples a dirty gray appearance. White samples absorb carbonic dioxide from the atmosphere, with formation of the carbonate and cyanate of potassium.

Testing Cyanide of Potassium. Since so much depends upon the quality of the cyanide used in making up plating solutions, the plater should be prepared to test each sample before using it. This can be easily done by means of a burette to hold 1,000 grains of water, graduated in 10-grain divisions, and furnished with a glass stopcock. This instrument resembles a long glass tube and is held by a wood clip lined with cork, mounted on a stand similar to that of a filter-holder. An ordinary graduated glass measure will also be needed, and this may be employed entirely in making rough tests of the sample, but in this case a larger quantity of the sample must be used up in making the test, and exact accuracy cannot be guaranteed.

The sample of cyanide to be tested must be accurately weighed in a balance showing a variation of one-hundredth of a grain. Either 100 grains of the cyanide should be weighed out, or some multiple of this quantity. The sample thus selected may be dissolved in any quantity of distilled water, but greater accuracy is secured in dilute solutions containing the salt in the proportion of 100 grains in 5 fluid ounces of water. This solution of cyanide should be contained in a tall glass beaker, as it will have to be shaken by hand during the testing process. Then weigh out 131 grains of pure double crystallized silver nitrate, dissolve in 1,000 grains of pure distilled water and place in the burette. Each division, or each 10 grains of solution, will contain 1.31 grains of silver nitrate, and this will satisfy 1 grain of potassium cyanide. If 100 grains of potassium cyanide is dissolved in the solution to be tested, each 10 grains of the testing solution will satisfy 1 per cent of cyanide. Deliver the testing solution from the burette gradually into the beaker containing the cyanide solution. At first the silver nitrate solution will curdle as it touches the cyanide solution, and the curdy precipitate will dissolve almost as soon as formed, or disperse on shaking the beaker. When the precipitated silver cyanide ceases to thus quickly dissolve, the beaker must be shaken or the liquid stirred with a glass rod until all the precipitate dissolves and the testing solution delivered with more care. Then go on delivering small quantities of the testing solution, two or three drops at a time, and shaking the cyanide solution between each delivery until the cyanide solution refuses to dissolve the last few drops of silver nitrate, and a few clots of the white precipitate are left undissolved. The number of divisions of nitrate solution thus used will show at once the percentage of real cyanide in the cyanide of potassium solution. Thus, if the 100 grains of potassium cyanide contain 90 grains of the active principle, 900 grains of the nitrate of silver solution will have been used, and this will have been contained in 90 divisions of the burette. The sample of cyanide of potassium thus tested will have contained 90 per cent of real cyanide and 10 per cent of impurities.

Cyanide of Potassium, Testing for Free. Free cyanide is the cyanide of potassium contained in the solution over and above that needed to form a solution of the double salt. The presence of this free cyanide is absolutely necessary to the proper working condition of the double cyanide silvering and gilding solutions, since they require excess cyanide to dissolve the anodes and keep up the right working strength of the baths. The quantity of free cyanide needed for this purpose can only be determined by experience.

ELECTRO-MECHANICAL PLATING, COLD GALVANIZING AND GALVANOPLASTY

Electro-mechanical Plating. A machine for the purpose of plating small articles without the necessity of stringing or wiring them is shown in Figure 41. The anodes, of whatever material it is desired to plate the articles with, are shown suspended in the vat. The cylindrical cage in which the articles to be plated are placed forms the cathode of the outfit. The cage is rotated slowly in the solution at a speed of from 15 to 20

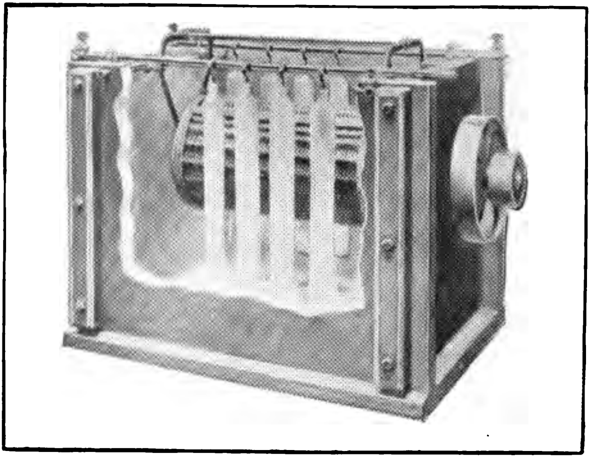

Fig. 41. Electro-mechanical Plating Apparatus.

revolutions per minute. Figures 42 and 43 show the old and the new methods of doing this class of work.

It has been demonstrated by actual experience that a very large number of small articles can be successfully plated in nickel, brass, copper or zinc by the use of this outfit, thus avoiding the handling, labor and cost of wire used in stringing. A partial list of work adapted for mechanical plating comprises: buckles, bolts, nuts, screws, nails, washers, trunk hardware, automobile parts, bicycle parts, sewing machine parts, typewriter parts, saddlery hardware, screw eyes, pulley wheels, musical instrument parts, hinges, general hardware.

Fig. 42. Old Method of Plating Small Articles.

Cold Galvanizing. It has been demonstrated that in the application of zinc by the electrolytic cold process a much smaller amount of protecting metal to the square foot is required than is necessary in hot or dip galvanizing. At the same time the protective quality of the electrically deposited zinc is greater, and the deposit more uniform than can be obtained where hot metal is used.

Tempered articles, coil springs, automobile and bicycle hardware, and like goods of comparatively small section or high temper, sometimes lose a part of their tensile strength or temper when subjected to the heat of the molten bath, which is about 774 degrees Fahrenheit. This is a disadvantage not present in the cold process. The following articles have been successfully treated by the electrolytic process: lag screws, bolts, nuts, washers, rods, angle irons, plumbers' hardware, sheet iron, hose couplers, spanners, wire clips, clamps, hinges, steel laths, hoop

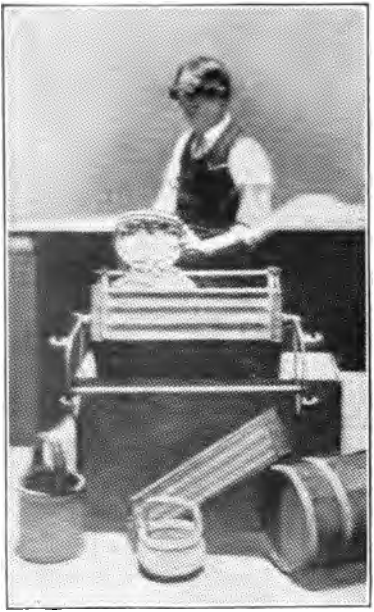

Fig. 43. New Method of Plating Small Articles.

iron, axles, wrenches, die stocks, braces and bars.

Galvanoplasty. This name was originally given to an electro-reproduction of printing type in copper, but has since been extended to similar reproductions of chased, engraved and rough surfaces, and also the replication in electro-deposited copper of images and statues. The process may be briefly described as follows: First, a mould of some plastic substance is taken of the subject to be copied, the surface of the mould is coated with a conductive film, and this film is connected to the wires employed to suspend the mould in the depositing solution. Second, the mould is suspended in a solution of copper sulphate, connected by suitable wires with the negative pole of an electric battery or dynamo, a plate of copper to form an anode is connected to the positive pole of the electric generator and suspended in the solution opposite to the mould, and an electric current is passed between them until the mould is covered with a strong coating of copper. Third, when the coat of copper on the mould is deemed to be thick enough for the purpose required, it is removed from the mould, well washed to free it from copper salts, allowed to dry, then strengthened by the application of solder or type metal to the back and mounted on a suitable block or support.

To ensure success in this process it is advisable to follow certain instructions relating to details dictated by the experience of others. These relate mainly to the choice and manner of working the moulding material, the arrangement of conducting wires, the choice and management of the depositing solution and the regulation of electric current employed in depositing the copper.

Moulds for galvanoplasty have been made of various materials, such as gutta-percha, bees-wax, sealing-wax, shoemaker's wax, paraffine, stearine, marine glue, sulphur, plaster of Paris, gelatine, and fusible metal. Gutta-percha may be employed as a mould to take the impression of a flat engraved surface, coin, medal, or similar object capable of bearing pressure without injury. The gutta-percha is made soft in scalding hot water, rolled in the hands under cool water to form a smooth ball, pressed on the oiled coin and worked all over it with the fingers, then put under pressure until it is cold and hard. Both sides of the medal or coin must be thus copied on separate moulds. Bees-wax may be used in a similar manner, but it is generally employed in a molten condition, when it is poured over the object to be

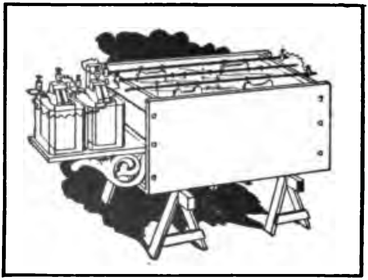

Fig. 44. Double Cell, Double Liquid Battery Plating Outfit.

copied whilst this is held in a suitable metal tray. The wax should be completely melted over a hot water bath, then allowed to partially cool before pouring it in the moulding tray. An ounce of dry white lead stirred well into each pound of molten wax is said to improve the mould. Beeswax has been extensively used for electrotypes of printers' forms and engravings. Paraffine, stearine and marine glue have been used in a similar manner, but are not recommended. Sealing-wax, shoemaker's wax and sulphur have been used by amateurs and experimenters, with varying success, in copying coins and medals. Plaster of Paris has been largely employed as a moulding material in copying images, statues, busts, and other works of art. The very best plaster must be had for this purpose. The work to be copied must be first oiled all over. The plaster is then mixed with water to the consistence of cream and poured at once over the object to be copied, and allowed

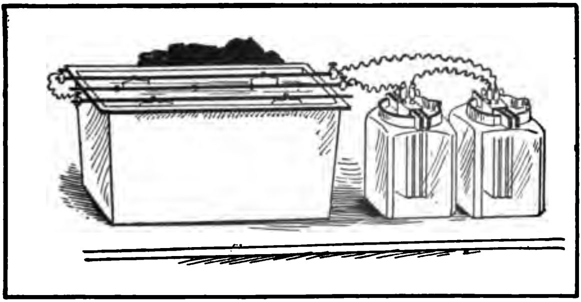

Fig. 45. Double Cell, Single Liquid Battery Plating Outfit.

to set hard before it is removed. Images, statues and similar rounded objects must be copied in two or more moulds separately. When such objects are much undercut, copies must be taken of them in printers' composition, a mixture of glue and molasses, and this elastic material employed as a mould for a copy in bees-wax. Gelatine is used in taking copies of finely-engraved plates and other works of art in which very fine lines only are employed. As this substance is readily soluble in water, a solution of it is employed, and this is poured on the object to be copied, then allowed to set hard by drying before taking off the film. As this film is liable to swelling and consequent distortion in the depositing solution, it is necessary to so treat it as to render it insoluble in water. This is attained by mixing bichromate of potash solution, or a solution of tannic acid with the gelatine before moulding, and exposing the mould to strong sunlight for several hours. Gelatine and also glue are rendered insoluble in water by this process.

As the moulding materials employed in making galvanoplastic moulds are either non-conductors or bad conductors of electricity, it is necessary to coat the surface to be copied with some conducting substance to serve as a bridge for the coating of copper. Moulds of gutta-percha, bees-wax, resinous substances and plaster of Paris are coated with black lead applied with a soft brush. Only the finest and best powdered black lead must be employed, and this is carefully brushed whilst dry into every crevice of the surface to be copied until every part has been covered with a film of the powder. Fine bronze powder mixed with two-thirds black lead forms a superior conducting film. Moulds of plaster of Paris must be previously well dried, coated with warm stearine or paraffine, baked in an oven, again well saturated with hot melted stearine or paraffine, then baked hard to prevent the plaster from absorbing the coppering solution. Moulds composed of gelatine, glue, and elastic or printers' composition, must be first rendered insoluble. This is done by mixing two parts of tannic acid with the solution to each 100 parts of the dry glue or gelatine employed, or by soaking the mould in a 10 per cent solution of bichromate of potash, then exposing it to strong sunlight for some hours. Moulds may be metallized by one of the following processes: Wet the surface with a strong solution of nitrate of silver, place it on a porcelain plate under a bell glass and expose it to the action of sulphureted hydrogen, hydrogen gas, or the vapor of phosphorus dissolved in carbon

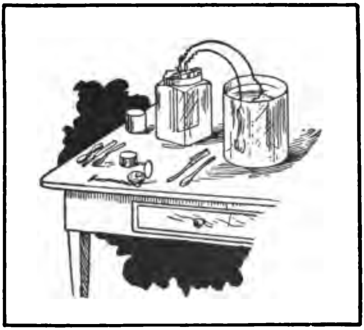

Fig. 46. Amateur Plating Outfit.

bisulphide. Wash the surface alternately at intervals of five minutes with a solution of one part silver nitrate in four parts of distilled water, and a solution of one part protosulphate of iron in three parts of distilled water. When the surface has a whitish-gray tint, rinse in clean water, immerse in the plating solution and connect at once to the battery. This preparation takes a film of copper rapidly. Wash the surfaces with iodized collodion, followed by a solution of silver nitrate, and after exposure to light a solution of protosulphate of iron acidulated with nitric acid.

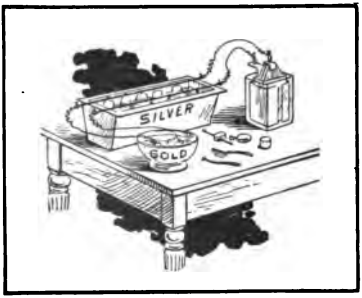

Fig. 47. Silver and Gold Plating Outfit.

The conducting surface of the metallized mould must be connected to the wire leading to the battery or dynamo. One, two, or more fine copper wires have their ends inserted in the edge of the mould, and the black lead or other conducting medium is carefully brushed around the ends of the wires to form a starting-point for the deposit. In copying statues or busts, a perfect network of such fine wires are formed, with their ends sticking into every remote part of the mould. These wires are then twisted around a main line wire to form the main conductor leading to the negative pole. Forms of type and similar large surfaces are connected by copper straps leading from the frame of the mould.

After connecting the mould in the plating solution with the dynamo, a spot of electro-deposited copper will appear on the surface of the mould connected to the end of the conducting wire, and this spot will spread all over the surface of the mould with more or less rapidity, depending on the condition of the metallic coat and that of the arrangements. A small mould may be coated in the course of a few minutes or within an hour, and yet have a good deposit. The rate of deposit is affected by the density and temperature of the solution, the relative size and nearness of the anode and mould and the strength of the current. The character of the deposit is also affected in a similar manner. A dense solution, one containing too much copper and too little water, a low temperature, low battery power, anodes too small, or too great a distance between the moulds and anodes, may result in a slowly formed and brittle deposit. A weak solution, one poor in metal, a high temperature, too high battery power, anodes too large, or moulds and anodes too close together, may cause a quickly deposited coat of a loose and porous structure. When the solution is too dense, the thickness of the deposit may be unequal, and dark streaks appear on it, but this same defect may be caused by density in the lower part of the solution only, due to want of stirring. The solution should be stirred every evening or at least once a day. The anodes and the zinc elements should be slightly larger than the surface to be coated. The temperature should be as near 60 degrees Fahrenheit as possible, but 5 degrees lower may be permitted. A voltage of from one to two volts is enough to deposit copper in good condition. Higher voltages may be required to push the desired volume of current through resistances, but a reduction of resistance is preferable to an increase of voltage. Much can be done in regulating the rate and character of the deposit by reducing the resistance in the outer circuit, by enlarging the anodes, using larger conducting wires and placing the moulds nearer the anodes. The resistance may also be increased, if desired, by the opposite

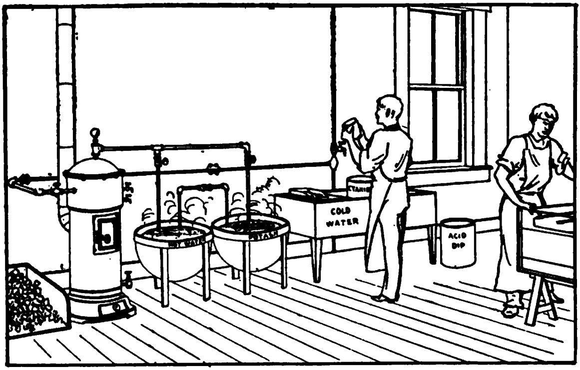

Fig. 48. Steam Generator Connected to Dipping and Scouring Kettles.

arrangement, or by the use of a resistance board in the circuit. Water will be required occasionally

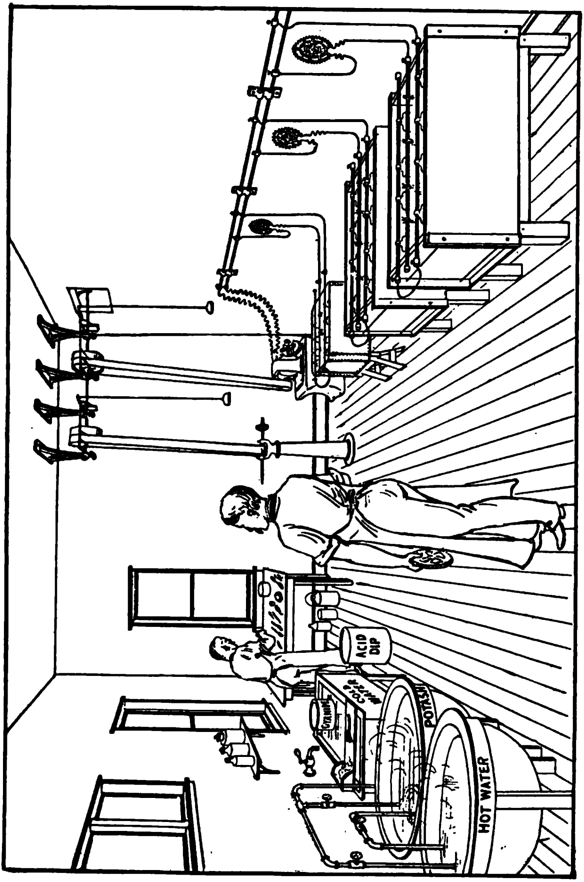

Fig. 49. Electro-plating Plant, Showing Dipping and Scouring Tanks and Plating Vats.

to make up for loss by evaporation, but no other alteration should be made in a good plating solution

When a sufficiently thick shell of copper has been obtained on the mould it should be taken out of the solution, rinsed in tepid water, and the two carefully separated to avoid any buckling of the shell. This should then be washed in hot water to free it from salts, then dried. When dry, lay it face downward on a flat surface, brush the back with soldering fluid, sprinkle it with grain soft solder, and place it on a hot plate to melt the solder, then brush the molten solder all over the back. This will give stiffness to the copper shell. The edges may now be trimmed with sharp shears and the electros mounted. The obverse and reverse of medals and coins may have their backs thickened and soldered together, or be soldered to flat discs of metal furnished with loops. They may then be silver-plated or gilded

Burnishing. If a very highly polished surface is required on spoons, forks, knives and heavily plated table ware, they are given to the burnisher, after they have been scratch-brushed, instead of to the polisher and finisher. In large establishments the work of burnishing is usually done by skilled female operators who have become skillful in the use of the tools by long practice.

The operation of burnishing is performed by means of steel tools. These tools are pressed on the surface of the plated article and rubbed to and fro until a bright, mirror-like surface has been produced.

The plated articles, having been scratch-brushed and dried in sawdust, are then taken in hand to be burnished. The work is first prepared by scouring the surface with very fine silver sand applied on a soft flannel pad dipped in warm soapy water. This is done to level down any roughness left from the scratch-brush, and so secure a uniform surface, but the amateur can effect a similar condition by first going over the surface on his polishing lathe and then brushing it with a soft brush dipped in warm soapy water. The work is then well rinsed in warm water and dried by rubbing with soft linen rags. The next operation is grounding. This is done with burnishers having a long thin edge. A set of burnishers of different sizes and shapes to suit the different surfaces to be burnished are shown in Figure 25.

These tools are mounted in wooden handles about four inches in length. The tool is held in the right hand with the handle resting on the back of the little finger near the first knuckle, the next three fingers on the upper part of the handle, and the thumb on the top to apply pressure. The work is placed on a pad of linen rag on a bench or table of convenient height. A lubricating liquid having been made of soap shavings and warm water, the burnisher is dipped in the suds and applied to the surface of the plated article in a slanting direction with moderate pressure. The strokes of the burnisher are so directed that each succeeding stroke shall slightly overlap that of its predecessor. The strokes must be all in one direction, and the surface thus gone over until all has been grounded. This will leave an imperfectly burnished surface. The whole is then gone over with a thicker steel burnisher in a similar manner to erase the marks left by the grounding tool. The burnisher must be kept well lubricated with soap-suds during the whole process, or it will heat, drag on the surface and strip the coat. It must also be wiped frequently to remove the dirty suds, and frequently polished on a piece of buff leather fixed on a slab of wood, such as a razor strop, hone or oilstone, charged with jeweler's rouge. Fresh suds must be made up for each day's work, and the burnishers must be kept free from the least trace of rust by frequent examination and polishing. Plated articles made of white metal, pewter, lead, and similar soft metals, will not stand burnishing, and only very moderate pressure may be applied to those made of copper or of soft brass. Thin deposits should be very lightly burnished, or not burnished at all if very thin.

A complete set of burnishing tools is shown in Figure 25.

Quickening Solutions. A plater is sometimes called upon to give a very thin and cheap coating of silver or gold upon articles which, from their nature and the metal of which they are composed, cannot be polished and prepared for plating in the ordinary way, such as photograph frames in thin, perforated designs, cast from a mixture of tin, lead and antimony or zinc, and various other designs. These goods are generally brought to the plater as soon as cast and must be plated immediately for a very slight cost.

The goods are strung on wires, dipped into hot water, then into a hot quickening solution, composed of a strong solution of bichloride of mercury and sal-ammoniac, which leaves a very thin film of mercury on the article. It is then transferred to a silver solution low in silver and strong in cyanide, kept in it a moment, rinsed in hot water and dried and lacquered immediately. The whole operation must be performed rapidly and the work kept constantly in motion while in the solutions. The entire process ought not to occupy over two minutes. Cheapness and speed are the sole requirements. When doing such jobs the plater must insist that the work be lacquered immediately. It will discolor if allowed to stand three or four hours without lacquer.

Another quickening solution frequently used on work composed of one of the many so-called German silver alloys, consists of a weak solution of potassium mercury cyanide in water. A weak solution of acidulated nitrate of mercury is also frequently used on work of this class.

These solutions are often useful in replating old work which has a tendency to refuse to plate in spots that have been badly corroded. There is no special rule to be observed in regard to strength, the main object is simply to coat with mercury spots that will not plate without it and the less mercury employed to amalgamate the surface the better for the work. Such solutions should be employed just before the work is put into the plating bath, and they should always be followed by hot rinsing and the work never allowed to dry.

Always keep the quickening solutions for the various metals separate from each other. Covered ten or twenty gallon stone jars are generally used to hold such solutions.

Stopping off Deposits. It is sometimes advisablo to ornament articles with various shades of gold in different parts, or with patches of gold, and silver, and copper. This is done by stopping off the deposit of gold or silver from the parts to be left uncovered with a suitable non-conducting varnish. After the gold or silver has been deposited on the part to be ornamented, the varnish is dissolved off with warm spirits of wine (grain alcohol). The following is a list of varnishes suitable for the purpose. Yellow stopping-off varnish: Best copal varnish colored with chromate of lead. This will protect metals in cold solutions only. Blue stopping-off varnish: Best copal varnish colored with ultramarine. Red stopping-off varnish: Best quick-drying copal varnish colored with rouge. These varnishes will dry in about three or four hours, and will resist hot cyanide solutions.

Points to Remember. An area equal to one square inch is required to carry 1,000 amperes. A copper rod 1 inch by 1 inch, or a strip of copper 4 inches by a quarter inch or 2 inches by a half inch will fill this requirement. If round wire is used an area equal to one square inch must be employed, or a conductor about 1⅛ inches in diameter.

The above specifications apply only to installations where the distance from the dynamo to the tank, measuring along the entire length of the conducting wire, is not more than 40 feet. For distances greater than 40 feet the size of the conductor should be increased as the distance is increased. Double the size of conductor is needed for a line connection of 80 feet, while 50 per cent increase in the size of the wire is required if the distance is increased 50 per cent over 40 feet.

In arranging branch wires from the main line to the tank it is necessary that the wires be large enough to carry, without heating, enough amperage to plate the full load of the tank. The capacity of the tank in square feet of work surface can be readily determined, then with a knowledge of the amperage required to plate a square foot of surface of the various metals the total number of amperes needed for a full tank and the size of the wire best adapted to carry the current can be readily determined.

For the convenience of platers, tables are given showing the number of amperes required to deposit a square foot of surface of each of the various metals, also weight and carrying capacity of the different sizes of copper wire and the loss in volts.

Amperes Required to Plate One Square Foot of Surface.		Carrying Capacity of Insulated Copper Wire.	
Metal.	Amperes.	Size.	Amperes.
Nickel . . .	4	No. 3 B. & S. G.	50
Brass. . . .	6 or 8	No. 0 B. & S. G.	100
Bronze. . .	6 or 8	No. 0000 B. & S. G.	180
Copper* . .	6 or 8	½ inch	225
Silver. . . .	2	⅝ "	350
Zinc.	1½	¾ "	500
Gold.	10	⅞ "	650
		1 "	750
		1⅛ "	1000

*Acid copper solutions require 10 to 12 amperes.

Voltage for Solutions. All platers should understand that different voltages are required to operate successfully different kinds of solutions, and that when a sufficient voltage is to be generated for a solution of the highest resistance, and at the same time utilized in low resistance solutions, the tank nearest the dynamo, with the customary method, receives the most current, and a tendency to burn and blacken is noticed to

WEIGHT, CARRYING CAPACITY AND LOSS IN VOLTS OF COPPER WIRE.

B. & S. Gauge.	Diameter in Inches.	Pounds per 1000 Feet of Bare Wire.	Weight per 1000 Feet of Insulated Wire.	Safe Carrying Capacity in Amperes of Bare Wire.	Loss in Volts per Ampere per 100 Feet of Double Line.
0000	.46	610.5	825	312.	.0098
000	.409	508.5	610	262.	.0123
00	.364	402.8	458	220.	.0155
0	.324	319.6	385	185.	.0195
1	.289	253.4	308	156.	.0247
2	.257	201.0	249	131.	.0311
3	.229	159.3	201	110.	.0392
4	.204	126.4	163	92.3	.0495
5	.181	100.2	133	77.6	.0624
6	.162	79.46	109	65.2	.0787
7	.144	63.01	90	54.8	.0992
8	.128	49.98	74	46.1	.125
9	.114	39.64	62	38.7	.158
10	.101	31.43	52	32.5	.199
11	.090	24.93	43	27.3	.251
12	.080	19.77	36	23.	.316
13	.071	15.68	30	19.3	.399
14	.064	12.43	25	16.2	.503
15	.057	9.86	21	13.6	.634
16	.050	7.82	18	11.5	.799
17	.045	6.20	15	9.6	1.088
18	.040	4.92	13	8.1	1.271

a marked degree. When metals such as silver and copper are to be deposited in connection with such metals as nickel and brass, a higher electromotive force is required, and considerable drop in voltage is demanded in the lower resistance solutions so as not to blacken the work.

Lacquering. The exercise of a little care in preparing articles for lacquering will add greatly to the finished product, insure satisfactory results, and cause the lacquer to become much more effective. In nearly all instances where trouble occurs the cause is directly traceable to either inexperience, imperfect cleaning, or carelessness in application. It is therefore necessary to observe the fundamental rules so familiar to all experienced users of lacquers. First, if the lacquer is too thin it will show iridescent colors. Second, if the lacquer is too heavy it will show a drip when employed for dipping. Third, if the lacquered articles show a white, milky cloud, it is always due to moisture or grease. If the directions and suggestions given here are carefully followed, perfectly satisfactory results will be obtained.

Dip Lacquers. Use a tin-lined wooden tank for holding the lacquer, or chemically enameled iron tanks. For holding dip lacquers use stoneware, glass, or enameled iron rectangular or cylindrical tanks. When not in use, cover with wood or sheet galvanized covers. Have the work as clean as for plating. Arrange the goods so the lacquer will run off properly. Allow them to drip over the drip tank until the lacquer stops flowing. Dry in a temperature of 100 degrees Fahrenheit, if possible, using a thermometer. Dip lacquers will dry in the air, but baking improves the finish. Use the lacquer as shipped until it shows a drip or nipple in drying. Thin only with thinner of same grade.

Brush Lacquers. Brush lacquers cannot be used as thin as dip lacquers. Use as thin as possible without showing rainbow colors. Give a flowing coat with a soft lacquer brush. A stiff brush will require a thicker lacquer, and will cause foaming or small air bubbles. All dip lacquers should be dried by heat in a temperature of about 100 degrees Fahrenheit. Thermometers for this work should always be used. Rainbow colors are in most cases caused by the lacquer

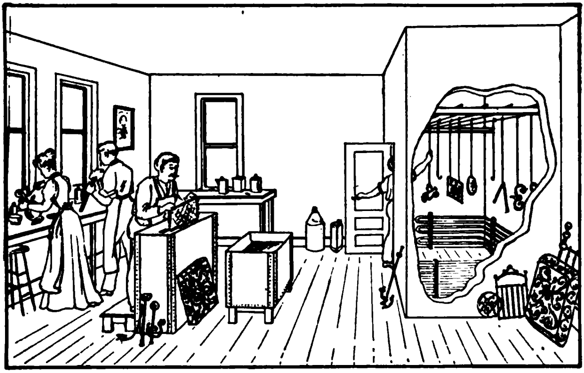

Fig. 50. Lacquering Plant.

being too thin or by carelessness in removing the crocus composition or rouge from the work. Grease is very injurious to lacquer.

Antidotes to Poisoning. To preserve the health of the workmen in the shop should be one of the chief considerations of the plater, since more and better work is done by healthy than by unhealthy workmen. An abundance of fresh air should be insisted on in all weathers, even if more clothing has to be worn. This can be insured without exposing any one to draughts, by the exercise of proper care in the ventilation. A want of pure air to mix with the poisonous fumes inseparable from a plating shop, must result in poisoning of the blood, since that passes through lungs charged with the poisonous air. For the same reason extra care should be taken to carry away from the workman any fumes raised in chemical operations, such as those from the preparation of solutions and from pickling operations. If the workmen must handle very frequently or continuously articles in contact with cyanide of potassium or solutions of this poison, the hands should be protected with rubber gloves, since cyanogen is readily absorbed by the skin, causing ill health. This absorption of cyanogen causes painful sores on the hands. These are best treated by dipping the sore into dilute sulphuric acid in 10 parts of water, freshly mixed, and enduring the consequent pain as long as possible. Then well wash the sore in warm soapy water and bind it up in a rag wet with soap-suds.

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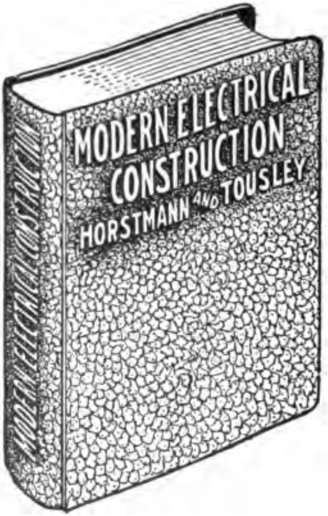

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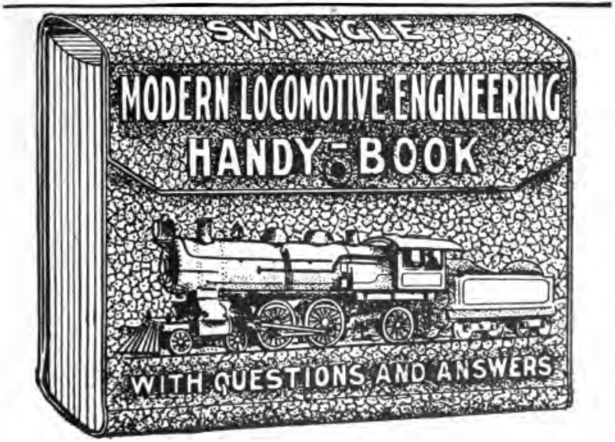

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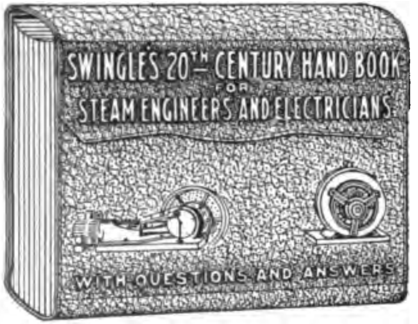

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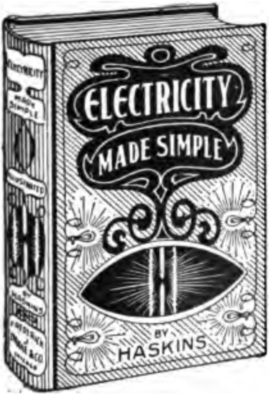

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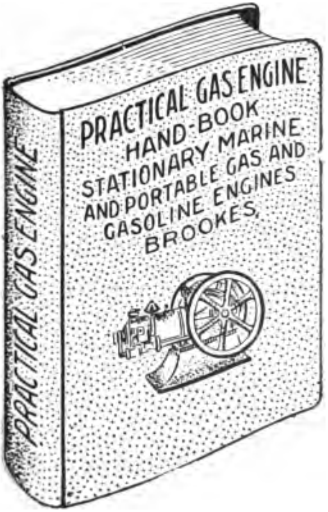

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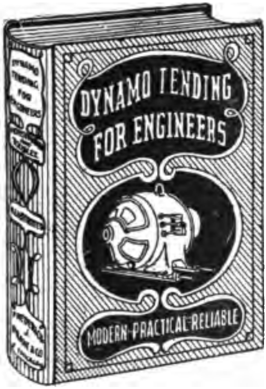

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